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Reports of fires appearing in the Quarterly are copies of or extracts from written reports forwarded to the Association. This Association, as a body, is not responsible for the statements or opinions of any of its members.

Public Service Building, Boston.
N.F.P.A. Headquarters on the Sixth Floor, Central Wing.

The Quarterly

Vol. 22 January, 1929 No. 3

Our New Offices. The office staff is rapidly getting accustomed to the head and foot room of our new quarters in the Public Service Building at 60 Batterymarch Street. To find ourselves at work in a space nearly twice as great as that in which we have been operating with steadily increasing confusion for the past five years is a novel experience. To turn back to a spot upon which five minutes before we have laid a file of papers and not find something piled on top of it affects us as pleasantly as the recent improvements made in the kitchen of a New York club affected its members. By long standing etiquette this club is never identified in public print, but we may quote from its recent bulletin:

Food can now be cooked in the kitchen by a chef without asbestos feet. He no longer has to stand on the stove. There is ample storage for our other egg, and the tripe which must be kept at all times for Don Marquis can now be housed in some other way than by hanging it on a line like a blanket. So vast are the ice boxes that it may be necessary to purchase a dog team for the use of the staff when they enter in search of steak.

The steel publication files used in the old offices have been reconstructed and extended to fit the new space, and a liberal amount of new shelving added. The most radical improvement is the conference room, where we may now receive our callers without disturbing the entire office.

* * * * *

Aviation Fire Hazards. Fire hazard is an important factor in the development of aviation, as has been shown in the articles on this subject published in the last two issues of the QUARTERLY (July, 1928, page 70; October, 1928, page 161). In the October issue a record was published of fires in planes and hangars, including 35 airplane fires in which 54 lives were lost. Since the publication of the October QUARTERLY the following airplane fires have been reported to the N.F.P.A. Department of Fire Record:

October 18, 1928. Polk, Pa. Airmail plane, on New York-Cleveland route, was destroyed by fire and the pilot cremated. It is believed that the plane took fire in the air.

November 2, 1928. Rantoul, Ill. Private plane crashed and burned. The pilot-owner was burned to death.

November 14, 1928. Washington, D. C. Navy plane took fire in forced landing. Two occupants saved themselves by swimming ashore.

November 21, 1928. Bristol, Pa. Twenty-passenger monoplane took fire in front of its hangar from unknown cause just prior to a scheduled christening ceremony. Two employees burned, but not seriously. Loss estimated at $75,000.

November 25, 1928. Bristolville, Ohio. An airmail plane crashed during a snowstorm, and took fire. The pilot was killed and a quantity of mail was destroyed.

December 1, 1928. Spur, Texas. Five men were burned to death when a tri-motored plane crashed and burned en route from San Antonio to Denver.

December 2, 1928. Duncan, Okla. An army officer was burned to death and his mechanic suffered severe burns when their plane crashed and took fire as they were taking off.

December 10, 1928. Hicksville, Long Island, N. Y. Student aviator, flying solo, crashed and was burned to death. Reports differ as to whether fire started while plane was in air or after the crash.

December 13, 1928. Tiffin, Ohio. Plane struck high tension wires. Flames enveloped plane, but pilot and passenger escaped.

December 16, 1928. Los Angeles, Calif. Two men were killed when a plane lost a wing in midair, fell, and burned.

December 16, 1928. Bedford, Ohio. Plane hit high tension wires, took fire and fell to ground. The pilot escaped with severe burns; the other occupant of plane was burned to death.

December 20, 1928. Huron, Ohio. An airmail plane on the Cleveland-Chicago night route was forced down in a snowstorm. The plane ignited after the crash and was destroyed. A part of the mail cargo was saved. The pilot was thrown clear of the plane and was killed but not burned.,

December 23, 1928. Chattanooga, Tenn. Six-passenger cabin plane, used on Atlanta-Chicago airmail route, crashed and took fire shortly after taking off. Four occupants were burned to death; one escaped.

January 1, 1929. San Juan, Porto Rico. Gasoline vapor exploded immediately after refueling amphibian plane from service boat in harbor. Two men on board were blown overboard but swam back to the plane and put out fire with extinguishers.

January 3, 1929. Boston, Mass. Plane ignited by welding torch used in repair operation. Plane was destroyed, but was pushed out of hangar in time to prevent other damage.

January 5, 1929. Stafford Springs, Conn. Air mail plane crashed and burned. Pilot was killed.

The fires listed above, reported from various sources, are not intended as a complete list of the fires during this period. Judging from the experience in other N.F.P.A. fire records, it may be assumed that this list represents but a fraction of the fires which have actually occurred. The exact circumstances of any given plane fire may be difficult to determine, particularly where the occupants of the plane are killed and a quick burning fire destroys all physical evidence. While it is not in all cases clear whether fires occur while the plane is in the air or following a crash, the best opinion seems to be that the great majority of airplane fires occur following crashes. Here again it is not always possible to determine whether the fatalities have been due primarily to the crash or to the ensuing fire. It may be assumed, however, that occupants injured in a crash, perhaps pinioned under wreckage and unable to extricate themselves without assistance, might be saved if it were not for the fire which so frequently occurs immediately following a crash.

There have not been included in the above list any fires occurring in foreign countries, although the occasional reports which reach the Executive Office indicate that the aviation fire hazard is an acute problem in Europe as well as in America. A forced landing and fire in a German plane on the Cologne-Berlin route, where three men were burned to death on December 11, is an illustration.

In addition to these accidents to planes and personnel, fires are also occurring on flying field property. The most important such fire reported since the last issue of the QUARTERLY occurred at the U. S. Army aviation field at Mineola, Long Island, New York, where the estimated property loss was $250,000. No planes were involved in this fire, the loss being buildings and equipment. Reports indicate an indirect loss from this fire which may have even more serious consequences than the direct property damage. This lies in the loss of records of experimental work which it is said will require two or three years to reproduce.

The distressing frequency of airplane fires and the large number of fatalities recorded indicate the existence of a very serious problem which must be solved in order to remove what appears to be a material handicap to the development of aviation. Unless effective measures are taken to reduce the hazard, the number of fires and attendant fatalities may be expected to increase as the number of planes in service increases, with a resulting popular fear of airplane fires which would tend to retard the development of air transportation.

Experience in other fields of the work of the N.F.P.A. has demonstrated that the great majority of fire losses may be avoided by the application of the measures of prevention and control which are detailed in the regulations and reports prepared by N.F.P.A. committees. There seems to be no reason why similar results may not be achieved in the field of aviation fire hazards. The organization of a committee on aviation fire hazards to function in a manner similar to that of other N.F.P.A. committees, is accordingly being taken up by the Executive Committee at its mid-winter meeting.

* * * * *

A Modern Fire Chief. The organization of the Rhode Island Fire Chiefs' Association is interesting as further evidence of the recognition by the modern fire chief of the growing possibilities of his office and influence. Chief Frank Charlesworth of the Providence Fire Department in promoting this new organization registers a conception of his responsibilities greater even than the most commendable one of making his own department efficient. Chief Charlesworth has served as a director in both the New England Association of Fire Chiefs and the International Association of Fire Chiefs, and knows the value of association work. He has successfully interested the chiefs of Rhode Island in the local association. There are already over one hundred members, including practically every chief in the state. Chief

Charlesworth was logically elected its first president. The association has held a series of meetings and called in men prominent in fire prevention work to address them. It developed that many of the chiefs in Rhode Island were volunteer and that they had problems which were seriously hindering their efficiency as fire fighters. As a result of these meetings Chief Charlesworth has drawn up two bills which will be presented to the Rhode Island Legislature at the coming session, one of which relates to the providing of proper authority for fire companies and particularly giving the volunteer fire company the right to "enter any property and to do whatever may be reasonably necessary in the performance of their duties while engaged in the work of extinguishing any fire." The other bill is in relation to the inspection of buildings to prevent fires, and is designed to give the volunteer fire companies the right to inspect all buildings for fire hazards and to order the removal of such hazards. The outlook for both of these bills is favorable. If they are adopted they will have a decided effect on the reduction of fire hazards and fire losses throughout the State of Rhode Island. Thus does the fire chief of Providence, the leading city of the state, extend his active influence throughout the commonwealth, bringing his fellow chiefs in touch with modern fire department methods and activities while determined to make his own department second to none in competence. Under his administration a fire prevention bureau has been organized in Providence. The work of this bureau has been markedly successful since its inception three years ago. Chief Charlesworth also has plans well under way for the establishment of a modern drill school and officers' training school, and is now advocating the establishment of a municipal salvage corps for his city.

* * * * *

Soot Removal. Chimney fires, unfortunately prevalent during the winter months, sometimes occur without serious consequences where chimneys are properly constructed with substantial walls and suitable flue linings, and where roofs are of the fire-retardant type. Fires in old unlined chimneys, especially in houses with wooden shingle roofs, more often result in the burning of the building if not promptly extinguished. Under any conditions chimney fires are manifestly undesirable, and the standard recommendation of fire prevention authorities, enforced in some cities through municipal ordinances, is that all chimneys subject to soot be cleaned periodically in order to prevent chimney fires.

The old-fashioned chimney sweeps, or the more recently developed mechanical methods of accomplishing the same result, are generally recommended, but there are also so-called chemical methods of soot removal. The U. S. Bureau of Mines has conducted a series of tests at its Pittsburgh station to determine the efficiency of soot removal compounds. Pending the prepara-

tion of a report on this work, the U. S. Bureau of Mines has released the following preliminary statement:

The conclusions from the tests are that a deposit on the soot obtained by throwing common salt, or mixture of common salt and zinc or some other salts lowers the temperature at which the soot will ignite and also causes it to more readily disappear by slow combustion for a small range of temperature below that of ignition. It follows that the action is one of helping the soot to burn and the flue gas must have the necessary temperature and contain sufficient oxygen that combustion can take place. Soot with deposits of such salts on it is more easily ignited by a spark, and burns more readily when so ignited.

The tests with household ranges and heaters showed that the soot did not burn at any great distance along the flue or chimney with a normal fire, and it was necessary to force the fire or lengthen the flame to make it burn.

Supplementary tests were made of heating equipment in residences. In some instances it was not possible to obtain a burning of the soot in the chimney; in others a vigorous burning was evidenced by the sparks emitted. No evidence was obtained in the limited number of tests made that the fire risk would be eliminated by the use of such salts. The possibility of a chimney catching fire would depend on chance conditions. All the evidence from the laboratory tests indicates that the burning would be more vigorous, and also it would be more easy to start when a salt was used. On the other hand, when using a salt there is a better chance of removing soot without starting a chimney fire, provided the cleanings are made frequently enough to avoid heavy accumulation of soot; also the lower heat required to start the treated soot burning does not require as vigorous a fire in the heater as it does when no treatment is used.

In view of the Bureau of Mines statement that "no evidence was obtained in the limited number of tests made that the fire risk would be eliminated by the use of such salts," it would appear safer to rely on mechanical means of soot removal.

Life Publishing Co.

THE CHIEF: Be careful where you throw that match, Ed.

U. S. Fire Loss Statistics for 1927.

Compiled by National Board of Fire Underwriters.

The United States fire loss for 1927 was $472,933,969, according to the final figures of the Actuarial Bureau of the National Board of Fire Underwriters to be published in the January issue of *Safeguarding America Against Fire.* This figure supersedes the original estimate of the 1927 loss made by the National Board earlier in the year and published in the July, 1928, QUARTERLY, page 30.

American Fire Losses Compared, 1926-1927.

Causes	Recorded Loss 1926	1927
Matches—Smoking	$30,160,233	$29,345,929
Defective Chimneys and Flues	23,111,618	19,523,904
Stoves, Furnaces, Boilers and their Pipes	21,977,114	17,986,432
Spontaneous Combustion	15,498,812	13,640,804
Petroleum and Its Products	14,978,599	12,691,718
Electricity	13,763,303	12,360,588
Sparks on Roofs	14,172,947	11,256,303
Lightning	18,205,326	9,084,630
Sparks from Machinery	8,324,071	5,812,466
Hot Ashes and Coals	6,851,460	5,171,491
Explosions	2,565,596	4,725,857
Sparks from Combustion	6,343,519	4,121,148
Open Lights	3,142,172	3,578,701
Miscellaneous Known Causes	4,191,737	3,408,359
Gas, Natural and Artificial	2,827,353	3,100,828
Incendiarism	2,202,492	2,403,615
Ignition of Hot Grease, Tar, Wax, Asphalt, etc.	1,880,240	1,699,208
Rubbish and Litter	1,809,136	1,035,454
Fireworks, Firecrackers, etc.	718,942	893,663
Steam and Hot Water Pipes	395,640	184,931
*Exposure (including Conflagrations)	54,074,554	45,082,747
Unknown Cause	202,369,737	171,038,429
Total	$449,584,601	$378,347,175
25% to Cover Unreported Losses	112,396,150	94,586,794
	$561,980,751	$472,933,969

*Losses due spreading fires originating from various causes.

The final figure for 1927 compares with the 1926 figure of $561,980,751 and represents a decrease of $89,046,782, or approximately 15%. This reduction in the fire waste shown by the final figures is even more than predicted in the January, 1928, QUARTERLY, pages 205 and 218, and may be accepted as conclusive evidence of the value of fire prevention efforts. The 1927 loss as

reported by the National Board is the smallest figure reported from this source in any year since 1920 and represents the first material drop in the fire waste curve, which has been mounting steadily for years.

The tables herewith show the distribution of the loss for the years 1926 and 1927 according to the several cause classifications and the distribution of losses by states. For convenience in reference, the annual losses reported by the National Board of Fire Underwriters are given by years from 1916 to 1927, 1916 being the first year for which these figures are available.

Comparison of U. S. Fire Losses, 1926-1927, by States.

State	Recorded Loss 1926	1927	State	Recorded Loss 1926	1927
Alabama	$5,730,599	$6,470,182	Nevada	$469,120	$281,317
Arizona	949,944	900,536	New Hampshire	2,324,188	1,997,797
Arkansas	7,978,139	4,710,283	New Jersey	17,360,657	17,450,048
California	26,979,121	20,000,272	New Mexico	623,480	585,295
Colorado	1,806,103	2,117,429	New York	58,476,246	48,559,113
Connecticut	7,050,814	5,755,693	North Carolina	8,103,687	6,569,743
Delaware	372,910	561,821	North Dakota.	2,192,854	1,914,089
Dist. Columbia.	820,663	806,344	Ohio	18,708,583	16,273,928
Florida	7,441,962	7,602,780	Oklahoma	6,797,630	6,438,201
Georgia	7,933,674	6,662,001	Oregon	4,998,660	3,110,627
Idaho	1,205,262	942,426	Pennsylvania	32,414,776	26,632,697
Illinois	32,553,614	27,940,545	Rhode Island.	2,728,829	2,167,723
Indiana	10,337,148	8,920,949	South Carolina	5,783,275	4,259,478
Iowa	6,554,522	5,424,164	South Dakota.	1,981,859	1,473,522
Kansas	5,275,156	3,898,337	Tennessee	9,130,154	7,643,290
Kentucky	8,347,371	6,518,358	Texas	18,814,893	17,401,085
Louisiana	9,703,362	6,933,711	Utah	1,741,031	1,338,746
Maine	3,688,315	3,870,172	Vermont	871,538	872,021
Maryland	6,239,398	3,785,401	Virginia	8,938,525	5,145,424
Massachusetts.	24,260,563	19,887,677	Washington	7,026,407	6,913,294
Michigan	17,041,249	16,367,390	West Virginia.	6,760,945	5,484,186
Minnesota	8,114,520	7,180,063	Wisconsin	8,314,020	7,052,535
Mississippi	6,369,083	5,332,890	Wyoming	428,197	450,609
Missouri	12,782,081	11,143,069	United States.	$449,584,601	$378,347,175
Montana	2,023,632	1,679,420	25% for Unreported Losses	112,396,150	94,586,794
Nebraska	3,035,842	2,920,494	Total	$561,980,751	$472,933,969

Annual Fire Losses in the United States from 1916 to 1927 Inclusive.

National Board of Fire Underwriters.

1916	$258,377,952	1922	$506,541,001
1917	289,535,050	1923	535,372,782
1918	353,878,876	1924	549,062,124
1919	320,540,399	1925	559,418,184
1920	447,886,677	1926	561,980,751
1921	495,406,012	1927	472,933,969

1928 Fire Losses—U. S. and Canada.

Compiled by New York Journal of Commerce.

Fire losses in the United States and Canada amounted to $301,267,560, according to figures compiled by the New York *Journal of Commerce* from their daily loss records. This represents a decrease of over $19,000,000 from the 1927 total, which in turn showed a decrease of $73,000,000 from the previous year. The 1928 total, which shows a decrease of 6% from the previous year, is the lowest figure reported from this source since 1919. Following the precedent of previous years, the heaviest monthly losses are registered for the winter months of 1928, the summer months showing relatively lighter losses. June, 1928, with a loss of $11,123,000, showed the lowest loss in any month for many years. The losses by months are given below for the years 1924 to 1928, inclusive.

The Fall River fire in February, 1928, with a loss of over $6,000,000, was the only major conflagration of the year. During the twelve-month period there were twenty fires involving a loss of one million dollars or over, as compared with twenty-five million-dollar fires in the preceding year.

The comparative statistics compiled by the *Journal of Commerce* are now available for a fifty-year period, as shown by the table on the next page.

Following is a tabulation of the fire losses by months for the years 1924 to 1928, inclusive.

	1924	1925	1926	1927	1928
January	$41,243,600	$41,210,400	$41,118,750	$37,910,600	$43,260,800
February	31,447,900	32,472,000	30,963,750	26,285,000	41,105,400
March	28,406,150	33,346,500	42,854,600	26,807,600	30,377,000
April	31,815,900	37,696,800	52,408,400	39,720,600	25,980,600
May	27,832,300	29,170,800	32,764,200	20,713,000	23,202,000
June	20,350,400	23,650,800	28,676,000	25,481,200	11,123,000
July	23,968,860	29,622,000	31,723,400	24,248,600	17,106,400
August	31,349,000	23,348,750	27,833,400	24,299,800	17,723,600
September ...	29,612,400	25,396,250	19,309,000	21,875,000	17,182,800
October	27,944,400	23,991,250	14,877,000	22,326,600	22,414,160
November ...	39,081,600	30,320,000	26,724,400	18,992,200	20,087,800
December	44,476,800	43,275,000	43,757,600	31,935,400	31,204,000
Totals....	$377,529,250	$373,500,550	$393,010,500	$320,595,600	$301,267,560

The fire loss figures of the *N. Y. Journal of Commerce* are based on estimates of fires involving loss of $10,000 or over, with a percentage added to cover small and unreported losses. These figures are not so accurate as, and are usually about a third smaller than, the statistics computed by the Actuarial Bureau of the National Board of Fire Underwriters which, because of the delays incident to compilation of complete records, are not published until later in the year. The *Journal of Commerce* figures are immediately available, and valuable for purposes of comparison.—ED.

$10,261,472,405 Since 1879.

The fire losses of the past fifty years, as compiled from the *Journal of Commerce* records, reach the vast sum of $10,261,472,405, as shown by the following table.

1928.....	$301,267,560	1911.....	$234,337,250	1894.....	$128,246,400
1927.....	320,595,600	1910.....	234,470,650	1893.....	156,445,875
1926.....	393,010,500	1909.....	203,649,000	1892.....	151,516,000
1925.....	373,500,550	1908.....	238,562,250	1891.....	143,764,000
1924.....	377,529,250	1907.....	215,071,250	1890.....	108,803,700
1923.....	389,192,200	1906.....	459,710,000	1889.....	123,046,800
1922.....	410,889,350	1905.....	175,193,800	1888.....	110,885,600
1921.....	332,654,950	1904.....	252,554,050	1887.....	120,283,000
1920.....	330,856,625	1903.....	156,195,700	1886.....	104,924,700
1919.....	269,000,775	1902.....	149,260,850	1885.....	102,818,700
1918.....	317,014,385	1901.....	164,347,450	1884.....	110,108,600
1917.....	267,273,140	1900.....	163,362,250	1883.....	110,149,000
1916.....	231,442,995	1899.....	136,773,200	1882.....	84,505,000
1915.....	182,836,200	1898.....	119,650,500	1881.....	81,280,000
1914.....	235,591,350	1897.....	110,319,650	1880.....	74,643,400
1913.....	224,728,350	1896.....	115,655,500	1879.....	77,703,700
1912.....	225,320,900	1895.....	129,835,700		
Total, 50 years.....					$10,261,472,405

Life Publishing Co.

THE GAY NINETIES.

The Chicago Salvage Patrol School.

The Chicago Salvage Patrol, which is under the direction of Chief Frank C. McAuliffe (Member N.F.P.A.), has developed, in connection with drills and training activities, a school for the training of the men, not only in the fundamentals of salvage work, but to give them a better appreciation of the technique of fire prevention as a whole. Chief McAuliffe believes that efficiency in salvage work demands more than the spreading of covers over stock, and this salvage company is therefore trained with this in view. The scope of the school is indicated by the following extract from the Rules and Regulations of the Patrol.

The school shall be composed of the following classes:

1. Officers' School.
2. Motor Operators' School.
3. Company School.
4. Probationary Patrolmen's School.

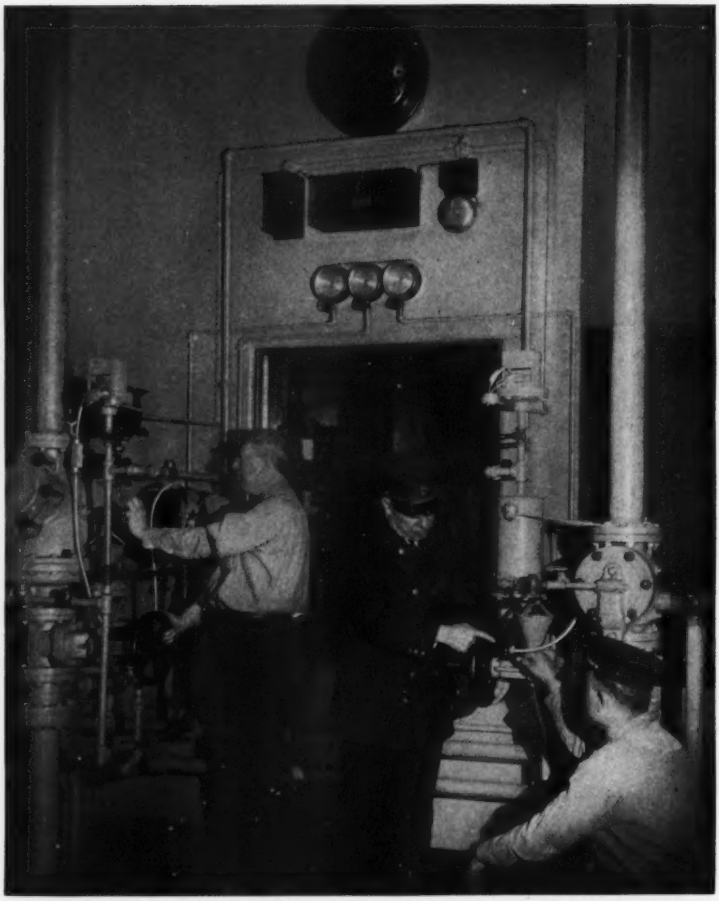
1. Teaching men how to spread covers at the Chicago Salvage Patrol School. Packing boxes, miscellaneous furniture, tables, etc., are used to simulate actual conditions in stores, dwellings, etc., where the men may be called upon to work. They are taught the best methods of using covers to control the flow of water used in a building where there is a fire, so that the water damage may be kept at a minimum. This room can also be used as a regular classroom.

2. Shutting off a sprinkler head by the use of sprinkler tongs, a small instrument about the size of a pair of pliers which can be inserted in the head, thereby stopping the flow of water much more quickly than it could be done by the shutting off of the entire system, a practice which is itself inadvisable. The sprinkler heads shown are two on the wall of a compartment which is arranged so that a fire may be built in it to demonstrate the action of sprinklers.

Courses of instruction shall be maintained in the following subjects:

1. Salvage work at fires.
2. General fire fighting.
3. Use of tools and appliances.
4. Care of apparatus, tools and appliances.
5. Covering roofs.
6. Fire watch.
7. Incendiarism.
8. First aid to the injured.
9. Private fire protection equipment.
10. Fire alarm, telegraph, including auxiliary systems.
11. Discipline and administration.
12. Inspection of buildings.
13. Gasoline motor engineering.

For convenience in instructing the men a large room on the second floor of one of the new stations of the patrol has been equipped as a schoolroom, which room has many interesting features. In general the room is equipped as is any schoolroom with a blackboard, chairs, etc., and can be used as a classroom for ordinary work. The room can be cleared, however, and with the aid



3. Instruction in the use of sprinkler equipment at the Chicago Salvage Patrol School. This picture shows the window looking into the compartment designed for staging fires. Inside this window is a heavy copper screen which distributes the heat developed evenly over the entire pane of glass, preventing its being cracked by the heat.

of packing cases and miscellaneous furniture it can be arranged to simulate a store occupancy with shelves, a dwelling, or any other ordinary type of occupancy in which the men of the patrol may have to work. The men are given instruction in the methods of opening doors with the least possible damage, being taught the use of a special tool for this purpose. The proper use of other tools, such as squeegees, brooms, shovels, ladders, plaster hooks and axes is also taught.

4. The panel of fire alarm and supervisory devices at the Chicago Salvage Patrol. With this apparatus and the sprinkler equipment shown in the preceding pictures the progress of a fire from the time the sprinklers open can be followed through the operation of the supervisory and alarm systems. The operation of automatic fire alarms, fire detecting systems and watchmen's supervisory equipment can also be demonstrated on this board.

The work does not stop here, however. Typical systems of sprinkler piping have been installed, of both the wet and dry pipe types, so that the operation of these may be demonstrated. Perhaps the most unusual detail of this particular school is a specially designed compartment in which a fire may be built and its action on sprinkler heads demonstrated. This compartment is at the front of the room and is visible from the main classroom through a large glass window. It is possible, therefore, to demonstrate the entire action of a sprinkler system on a fire, showing how the heat rises and opens the head, and how the fire is extinguished. At the same time the operation of water flow alarms, dry pipe valves, etc., may be observed. The men are then taught to shut off the head temporarily with a tool something like a pair of pliers which can be inserted in the head and the flow of water temporarily stopped. The use of the sprinkler tongs at fires has proven very satisfactory, as they stop the flow of water much more quickly than it could be stopped by shutting off the whole system, which is frequently undesirable. Further initiation into the mechanical details of the operation of private and public fire alarms, supervisory systems, etc., is given, a panelboard containing most of the common types of fire alarm and supervisory apparatus being provided in the schoolroom.

The school also offers an opportunity to teach the men the importance of inspection work in connection with salvage operations. The men of the patrol are required to make inspections of buildings in which they are likely to be called upon to work, and special instruction in the school enables them to keep in mind just what to look for. They study the skidding of stock and the construction of cases and shelving, the piling of stock in such a manner as to permit quick and efficient covering, the marking of drains and catch basins in basements, and the keeping of these basements clear and unobstructed.

The Chicago Salvage School might well serve as a model for cities which are contemplating the equipment of a schoolroom for fire department or salvage corps instruction. Practically all of the instruction given at this salvage school would be equally valuable for firemen and fire officers.

Fire Prevention Week Results.

By T. Alfred Fleming,
Chairman, N.F.P.A. Committee on Fire Prevention and Clean-Up Campaign.

A survey of the results of International Fire Prevention Week, October 7-13, 1928, compiled on the basis of reports received from cities of the United States and Canada, shows most worth while results for this department of the Association's activities sponsored by the Committee on Fire Prevention and Clean-Up Campaign.

The effectiveness of the campaign for Fire Prevention Week is shown in the reports of two hundred and fifty-five cities. While the average weekly fire loss of these municipalities for the previous six months was $994,048, this loss was practically cut in two due to the concentrated inspection and educational program. For the week of September 30th (preparatory to Fire Prevention Week) the fire loss averaged $528,333, for Fire Prevention Week, October 7th to 13th, $533,973, and for the week following $570,080. Of these cities, 72 reported no fire loss during the week beginning September 30th, 66 suffered no loss during Fire Prevention Week, and 72 escaped damage from burning throughout the following week. Cities reporting losses of $35 or less were as follows:

Week of September 30th	25
Fire Prevention Week	23
Week following	21

Merit judges were appointed to select the city in each State and Province having the most constructive program and making the most complete report of activities. They also compiled a list of the cities whose program stood highest in the United States.

The judges appointed to review the reports of the different municipalities in the United States were Mr. Ralph Richman, editor of *Fire Protection*, Cincinnati, Ohio; Mr. A. S. Dickinson, Director of Conservation of the

Motion Picture Producers and Distributors of America, and Mr. Chas. Vilade, who substituted for Mr. Wm. B. White of the New York Board of Fire Underwriters. The chairman of the Merit Committee in Canada was Hon. George F. Lewis, Deputy Fire Marshal of Ontario.

This merit competition is not to be confused with the all-year-round program of activities known as the Inter-Chamber Fire Waste Contest, conducted by the Chamber of Commerce of the United States, as the accomplishments of Fire Prevention Week are but one of the many parts of any program conducted by permanent fire prevention committees as contemplated by the Inter-Chamber Fire Waste Contest.

The following are the merit awards:

State	Winning City	City Receiving Honorable Mention
Alaska	Ketchikan	Fairbanks
Arizona	Tucson	
Arkansas	Eldorado	
California	Fresno	
Connecticut	Hartford	
Delaware	Wilmington	
Florida	Ocala	Fort Lauderdale
Georgia	Waycross	
Idaho	Boise City	
Illinois	Moline	
Indiana	Hammond	Indianapolis
Iowa	Fort Dodge	Des Moines
Kansas	Wichita	
Louisiana	New Orleans	
Maine	Portland	Lewiston
Maryland	Baltimore	
Massachusetts	Springfield	Fitchburg
Michigan	Fremont	Albion
Minnesota	Faribault	St. Paul
Mississippi	Pass Christian	
Missouri	Kansas City	
Nebraska	Omaha	
New Jersey	Hoboken	Burlington
New Mexico	Carlsbad	
New York	Utica	Watertown
North Carolina	Asheville	
North Dakota	Bismarck	
Ohio	Cincinnati, Lakewood—tied	
Oklahoma	Ponca City	
Oregon	Portland	Marshfield
Pennsylvania	Pittsburgh	
Rhode Island	Providence	
South Carolina	Charleston	
South Dakota	Huron	Pierre
Tennessee	Memphis	

State	Winning City	City Receiving Honorable Mention
Texas	Dallas	Fort Worth and Wichita Falls
Utah	Logan	
Vermont	Springfield	
Virginia	Petersburg	
Washington	Spokane, Bellingham—tied	Colfax
West Virginia	Huntington	
Wisconsin	Milwaukee	
Hawaii	Hilo	

Cities in the United States which were outstanding in their activities:

Cincinnati, Ohio.
Dallas, Texas.
Fort Dodge, Iowa.
Hartford, Conn.
Lakewood, Ohio.
Milwaukee, Wis.
Springfield, Mass.
Utica, N. Y.

Fire Prevention Week Activities in Canada.

The following results are taken from the Report of the Inter-City Competition regarding Fire Prevention Activities in the Dominion of Canada, 1928:

Class "A" (Cities with population of 100,000 and over)

Province of British Columbia . . Vancouver
Province of Manitoba . . . . . Winnipeg
Province of Ontario . . . . . Ottawa 1st, Toronto 2nd
Province of Quebec . . . . . Quebec

Class "B" (Cities with population of 25,000 to 99,000)

Province of Alberta . . . . . Calgary
Province of British Columbia . . Victoria
Province of New Brunswick . . . St. John
Province of Nova Scotia . . . . Halifax
Province of Ontario . . . . . Brantford 1st, Kitchener 2nd
Province of Quebec . . . . . Hull 1st, Outremont 2nd, Sherbrooke 3rd
Province of Saskatchewan . . . Saskatoon

Class "C" (Cities with population of less than 25,000)

Province of Alberta . . . . . Lethbridge
Province of British Columbia . . Prince Rupert 1st, Nanaimo 2nd
Province of Manitoba . . . . . Portage la Prairie 1st, St. Boniface 2nd, Brandon 3rd
Province of Nova Scotia . . . . Glace Bay 1st, New Glasgow 2nd, Yarmouth 3rd
Province of Ontario . . . . . Kenora 1st, Brockville 2nd, Owen Sound 3rd
Province of Quebec . . . . . St. Hyacinthe 1st, Rivière du Loup 2nd, La Tuque 3rd
Province of Saskatchewan . . . Prince Albert 1st, North Battleford 2nd, Weyburn 3rd

Madrid Theatre Fire, Sept. 22, 1928

By Fire Chief Petersen, Düsseldorf, Germany.

When on Monday, the 24th of September, 1928, the evening editions of the daily papers published in display letters the first news regarding the theatre catastrophe at Madrid, according to which several hundred persons (some papers said as many as 500) had died at the fire, and about 300 persons were reported to have been injured, more than 100 of them badly, I considered it indispensable, in view of the magnitude of the disaster, to determine the cause of the catastrophe right at the place where the accident had occurred.

While I endeavored to ascertain the most convenient connection with Madrid, either by airplane or by rail, our chairman of the Society of German Fire Engineers, then on furlough, called me by telephone and required of me, as chairman of the theatre committee, to go as quickly as possible to Madrid in the common interest of the society, in order to make deductions from the events which had occurred and to secure all details also as concerns the experience secured from the fire.

Inasmuch as the Prussian Fire Brigades Council considers that the suggestions for improvement of a new set of rules for theatres as submitted three years ago by the Society of German Fire Engineers to the authorities to be also an affair of its own, I immediately telephoned Chief Fire Director Gempp at Berlin, at present president of the Prussian Fire Brigades Council, who also had just read the first reports of the occurrence in the evening papers.

We agreed on a joint trip which was to be undertaken as quickly as possible, met on the 28th of September at Cologne and reached Madrid on the 29th of September at 11 P.M. The following Sunday, at 10 o'clock in the morning, we were already at the scene of the accident, guided there by the Madrid fire chief as well as by the authorities and representatives of the press.

Our assumptions, exchanged in the course of the trip, that the reports of the various papers were incorrect, according to which the theatre had been an old wooden building, and also that the firemen had not appeared until 20 minutes after having been called, were fully confirmed. Also, fortunately, the reports as to the large number of dead and injured proved to be exaggerated.

The "Teatro de Novedades" is located in the oldest section of Madrid and adjoins a narrow street, called Calle de St. Ana, directly only by means of the back of the stage; this street is only seven meters (23 ft.) wide.

For the rest, it is otherwise entirely surrounded by buildings. The main entrance is at the Calle de Toledo. From there, by means of a passage about 23 meters (75 ft.) deep and 4.5 meters (15 ft.) wide, one reaches the entrance

Translated from *Feuerschutz*, the monthly publication of the Society of German Fire Engineers.

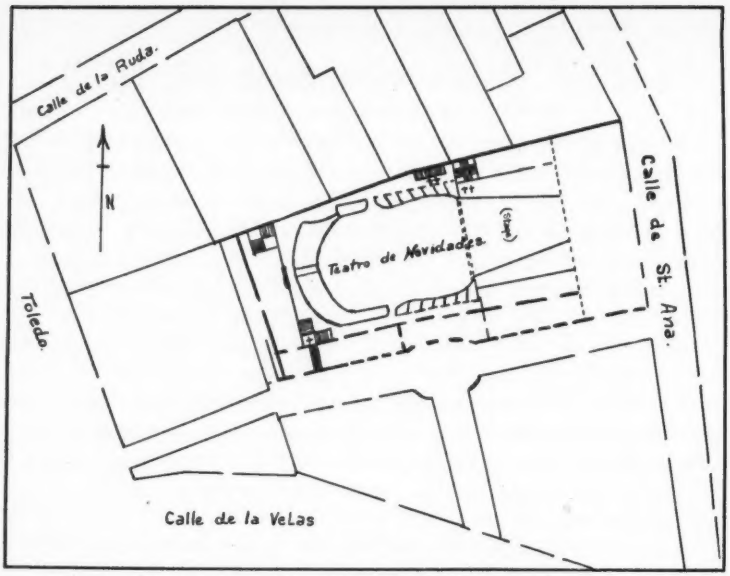


Diagram of the Teatro de Novedades, showing inaccessible location in center of block.

proper. In front of the southern longitudinal side of the theatre the passage widens in the direction of the Calle de St. Ana and at about the middle of the theatre it makes a right angle turn as a passage to the Calle de las Velas.

The theatre was first built as a military barracks, later on reconstructed into a circus, and in 1857 it was established as a public theatre. From this time onward improvements for increasing the security were constantly made.

The theatre must be considered mostly as a solid construction. Where it consisted of wooden framework filled with masonry, it was heavily plastered on both sides. The iron columns and beams were not protected in the auditorium. The supporting columns of the stage section were heavily coated with reinforced cement. The stairs were wooden steps which were plastered below. The roof construction consisted of wood and was plastered on the lower side in the auditorium.

The auditorium had a capacity of, in round figures, 2,400 people, and consisted of the orchestra and the three galleries, which extended around the entire auditorium as far as the walls where the stage section began.

The exit conditions from the auditorium cannot be designated as unfavorable. For the 660 orchestra seats, both on the longitudinal side as well as at the rear, there were numerous comfortable exits. For the frequenters of the galleries there were two staircases, each 1.6 meters (63 in.) in width, at the

corners of the wall opposite that of the stage wall. Of these, one of the stairs led to the foyer, located outside of the auditorium, with a direct exit to the open air, while the second stairway opened into the lower story of the auditorium. Moreover, there was a narrow connecting stairway between the lower story and the first gallery at the north side. Moreover, as far as can be ascertained, the width of the doors in the passages was sufficient.

The southern side of the lower story had promenades 4½ meters (15 ft.) wide, whose doors and windows opened direct upon the passage leading past the same.

The stage section was separated from the auditorium by a solid wall in which, however, there were several openings closed by only wooden doors. The stage had an entire width of about 20 meters (65 ft.), and a depth of about 16 meters (52 ft.).

There was an iron curtain. This was not constructed solidly, as is done here, but consisted of an iron frame with a wire netting. Between the storeroom for the side scenes and the auditorium there were located, laterally from the stage, the dressing rooms for the actors in several stories.

A special stairway to the actors' dressing rooms, which at the same time led to the various rigging lofts, was open in the northwestern corner of the stage. Also the bin for the coal supply and the heating room for the central heating installation were located in the stage section. At the time of the fire the theatre was not heated. The illumination was electrical. But the only switching board for the entire theatre was located on the stage. As an emergency illumination there were small red bulbs provided above the exits, but without any special current source.

Ventilation existed only in the ceiling of the auditorium above the chandelier. There was no such ventilation in the stage section.

The decorations in the stage section are declared to have been impregnated according to the legal provisions. The stage and the storeroom were full of decorations on the day of the fire.

For fire protection there was a spraying device for the curtain provided on the inside of the stage section, which, according to statements received, had two supplies. This could only be actuated from the stage, like the curtain.

There were two wall hydrants with hose to the right and left on the stage. A few small hand extinguishers completed the protection on the stage. In the auditorium there were only a few extinguishers distributed.

The Madrid water supply system is under a pressure of at times up to 15 atmospheres (220 lbs. per sq. in.), in comparatively limited pipe cross sections. As for hydrants, there are only flush hydrants at distances of about 40 meters (130 ft.).

Fire alarm apparatus existed neither in the theatre nor anywhere else in Madrid. A communication could be sent only by the telephone, which was on the stage.

In general, for theatres of the size of the Novedades, two men of the professional fire department are appointed as safety watchmen, whose station during the performance is to the right and left of the first wing passage. One of their main tasks is to tend the iron curtain, the curtain spray, and the fire apparatus.

There are general theatre regulations for protection against fire, just as in Germany. In fact they are in part even more severe than with us. Their application, however, meets great difficulties, particularly in private theatres. Owing to this, this theatre was to have been closed in 1925 unless the improvements were made.

Story of the Fire.

The occurrence which on Sunday, the 22nd of September, led to the terrific catastrophe, was as follows:

An afternoon performance was scheduled for 7 o'clock (the evening performance starts at 11 P.M.) which had not been reported to the police. Hence the fire department was not advised as to the function and did not furnish any safety watchmen.

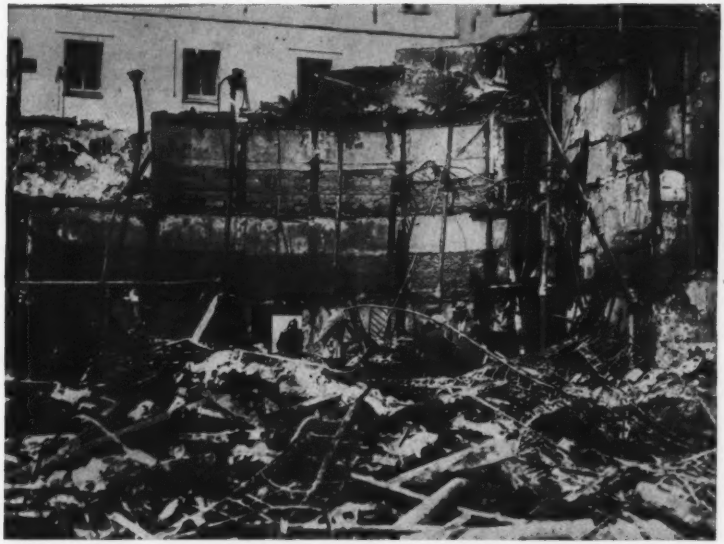
Just as here, the matinées are visited particularly by women and children. At the time of the performance there were 600 persons in the theatre. The two-act operetta and fairy show, "La Mejor del Puerto," was given. On the stage the artists and theatre staff amounted to about 150 to 200 people. The orchestra consisted of about 30 musicians.

In the second scene of the second act there is a ballet performance which is staged on a ship lighted by Chinese lanterns. In this connection a Chinese lantern was set afire, as is claimed, by a short-circuit, and caused the burning of the adjoining Chinese lanterns and of the wings.

While the artists continued their play the stage director called to the workmen: "Tirar" (lower away! let down!). Instead of that the workmen pulled the Chinese lanterns upwards, as "Tirar" also signifies "Pull up!" and therefore the curtains and soffits caught fire rapidly. The stage director wanted to let the iron curtain down, a matter which he was however unable to do because of some trouble. In lieu of that, and with a view to screening the fire from the public, the stage director let down a light advertising curtain. The bandmaster, who had observed the commencement of the fire, continued to conduct the orchestra.

After the letting down of the advertising curtain the actors and the personnel left in full flight towards the back of the stage. All except three were able to save themselves. One of them was the prompter and the others were workmen.

Until then the public had not fully realized the occurrence on the stage. They remained quietly in their seats. Only when by the severe drafts of the open doors and windows, used by the stage hands in their flight, the light



Wide World.

Ruins of the Teatro de Novedades, Madrid, after the fire of September 22, 1928, when 68 persons were killed.

curtain was raised high into the auditorium did the public suddenly see the stage, which was burning in all its parts.

The lights and the emergency illumination went out and only the sheet of flames on the stage illuminated the auditorium. In spite of the terrific appearance the public kept quiet and flowed towards the exits. The orchestra patrons reached the open air safely with the exception of a few, although the majority did not run to the nearest doors but went to the one main entrance which was mostly used. This was also done by the gallery patrons, who for the most part rushed towards the one staircase which does not open into the outer air but into the orchestra section. Owing to this, of course, a terrific stoppage and a complete jam took place at the exit located at this staircase. The fire then extended over the entire auditorium and filled it with flames and heavy smoke. Dressing rooms, galleries and the roof caught fire. Because of the jam on the gallery stairway (it is called today "la escalera de la muerte," the stairs of death) some of the patrons of the gallery jumped into the orchestra. On the death stairs there were found 48 dead, most of them by asphyxiation. In all 68 deaths were counted. Of the 200 injured 60 were badly hurt.

If the patrons had distributed themselves without allowing themselves to be overcome by the panic when leaving over the exits and stairs available, an evacuation of the theatre without danger would have been possible in spite

of the rapid development of the fire and in spite of the existing lack of safety measures and means of exit.

This is also particularly shown by the fact that after the arrival of the fire department the latter went eight times over the staircase, which, with the stairs of death, is located on the same back wall and leads into the open air, saving 28 lives.

It has been learned that these stairs were used only in the first moments by a number of gallery patrons, but later on not at all. Thus a patron of one of the boxes, who was in the bathroom or water closet of the stair landing of the second upper story, was unable to leave the same on account of the heavy flow of human being on the steps, which made impossible the opening of the door which opens on the stairs. He lit a cigarette, waited and was able later on to go down the staircase, which was devoid of all human beings, while all pushed towards the other stairway, the "Stairs of Death," on which the corpses were already accumulating.

The main fire station was advised seven times by telephone of the fire which had begun, and appeared on the scene with the first vehicle three minutes after the first alarm. The remaining four stations arrived shortly in full equipment. They had great difficulty in getting along the narrow street, which is only seven meters wide (23 ft.), because the fleeing patrons of the theatre and the inhabitants of the houses on the street had crowded the street so.

The first attack on the fire was effected through the main entrance over the stairs of the boxes described above and used but little by the public as a means of exit. During the first rescue work the roof and the balconies collapsed, burying the last persons who were trying to save themselves. On the whole the fire department acted very skillfully and wisely and did everything that was possible. After the collapse all the buildings around the theatre (framework with a great deal of wooden construction in the roof) were caught by the fire so that a very essential danger was caused for the entire quarter.

In all the fire department employed, from five motor-driven fire engines, tanks and hydrants, 25 nozzles; 2,336 meters (7,650 ft.) of 45 mm. ($1\frac{3}{4}$ in.) and 1,260 meters (4,125 ft.) of 70 mm. ($2\frac{3}{4}$ in.) hose was used.

The work of clearing up was not finished when we visited. Of late two more corpses were found, while in the hospitals two more injured died.

The actors and the orchestra continued their play a few days after the fire in the "Teatro Chueca," which was built five years ago as a moving picture theatre. We therefore had an opportunity on the 30th of September, in the evening, after 11 o'clock P.M., of being present at the performance and of observing the scene in the course of which the accident occurred. The theatre was crowded with humanity up to the last scene. I counted 1,700 persons, including children down to four years.

The disaster reminds one extraordinarily of the catastrophe in the Iroquois Theatre in Chicago in 1903, where 571 died, and the moving picture house at Montreal in 1927, where 78 people died. Both here and in Chicago it was a matinée which had not been reported to the police. In both cases there was no safety watch present in consequence thereof.

Here, as in Montreal, the public, in consequence of the panic, congregated at one single exit, respectively at one single stairway.

In all these cases there was not a sufficient number of tenders for the safety devices and not enough trained inspection personnel at the exits.

In the "Teatro de Novedades," according to our German ideas, the safety devices, particularly for the stage section, were by no means sufficient. Also the illumination and ventilation equipment was insufficient. The same things apply as to the marking of the exits. The fire alarm apparatus was entirely lacking.

And yet, in spite of these defects, the great catastrophe would not have taken place if the panic had not been started at the last moment and if the visitors of the balconies had not all streamed to one stair, but had used all the stairs and exits, particularly the ones located in their immediate neighborhood.

The disaster in the auditorium took place after the advertising curtain had been driven up towards the auditorium, in a very short time. It must be observed in this connection that normally this theatre could be entirely evacuated in from five to eight minutes, because the visitors do not collect at the check rooms, as is the case with us.

Comparing the conditions in the "Teatro de Novedades," which has existed since 1857, with our German theatres, it appears that we have in Germany a large number of theatres which are just as old and whose exit conditions are not more favorable than those of the theatre where the accident occurred.

The catastrophe in Madrid calls for a thorough retesting of the existing safety devices in all old theatres located unfavorably, by the authorities and officials, in strict application of the police rules, a constant checking prior to each performance, no performance without safety watch, instruction and checking of all inspecting persons in the auditorium and stage sections.

Above all it is necessary that, particularly in theatres with unfavorable exit conditions, every patron, whether by printing on his ticket or on the program or even on his seat, is reminded that he should use the exit nearest him even when the theatre is evacuated under normal conditions.

Only by such an education of the public and of the doorkeepers can the consequences of a panic be avoided or at least considerably lessened in any serious emergency case.

Classification of the Hazards of Liquids.

By A. H. Nuckolls, Chemical Engineer,
Underwriters' Laboratories (Member N.F.P.A.).

Section II of the Underwriters' Laboratories' List of Inspected Gas, Oil, and Miscellaneous Appliances includes a large number of liquids of various trade names classified as to fire hazard only. These liquids are listed under several different headings, according to their various commercial uses, including cleaning fluids, floor oils, insecticides, refrigerants, solvents, thinners for paint and varnish, and waterproofing material. Our testing and listing of liquids are primarily for the purpose of providing fire insurance organizations and inspection authorities with a definite classification of the relative fire hazard of these products as described below.

Although many flammable liquids differ widely from each other both in respect to fire hazard and chemical composition, they have certain chemical and physical properties in common which constitute their fire hazard. These common properties differ in a degree corresponding closely to the fire hazard of the liquid. A method has been worked out on this basis whereby it is possible to measure and correlate the most important hazardous properties in terms of our knowledge of a number of well-known liquids, such as gasoline, kerosene, and paraffin oil, the hazards of which have been well established by field experience. The method embraces a general classification as well as a numerical scale of hazard ranging from 0 to 100 plus, as follows:

General Classification	Numerical Scale
†Ether class	100-110
Gasoline class	90-100
*Kerosene class	30- 40
**Paraffin Oil class	10- 20

In our List a liquid is classed in respect to fire hazard with some well-known product such as kerosene or paraffin oil, and given a corresponding numerical value.

Work on this method of classification of the hazards of liquids was begun in the year 1908 by the author. Acknowledgment is due the late W. H. Merrill for valuable assistance. Constructive criticism has been received from members of the Laboratories' staff, and from a number of underwriters. Acknowledgment is also due Messrs. Tibbals and Matson, Dr. Doubt, and Mr. Maitre of our Chemical staff for helpful suggestions in the preparation of this article.

The method has been applied to liquids listed by the Laboratories for the past 16 years, during which period considerable progress has been made in standardizing the test work and simplifying the procedure.

†Pure ether is rated 100.
*A standard kerosene 100° F. (Closed Cup) is rated 40.
**A paraffin oil of 440° F. flash (Closed Cup) is rated 10.

Following is: first, a description of the important hazardous properties of flammable liquids; second, a study of the relationship of these properties to the fire hazard as determined by our method of classification, together with a tabulation of test data covering a large number of flammable liquids; third, the procedure a manufacturer is requested to follow who desires to secure a classification and listing of a proprietary liquid by the Laboratories.

Hazardous Properties.

The hazardous properties common to most flammable liquids, which can be determined and measured by laboratory tests, include: volatility, ignition temperature, flammable or explosive limits, combustion intensity (combustibility), vapor density, toxicity, and nature of products of combustion. In addition, it is necessary to determine whether or not a liquid is chemically stable, that is, whether there is any inherent tendency to ignite spontaneously or to undergo decomposition under conditions of use and storage, resulting in the formation of a more hazardous product. The reactions of the liquid with water and other common substances (hazards by combination) are also studied.

Volatility.

By volatility is here meant the *tendency** of a liquid to assume the vapor state; that is, evaporate. This tendency known as the vapor pressure is possessed in very different degrees by various liquids. Gasoline in an open vessel evaporates much more rapidly than kerosene. Paraffin oil on the other hand evaporates very slowly at the ordinary temperature.

The volatility of flammable liquids is of very great importance from a fire prevention standpoint, inasmuch as the combustion attributed to flammable liquids is in nearly all cases a chemical reaction between the vapor of the liquid and the oxygen of the air. It will be noted in this connection that the temperature at which a liquid passes freely into vapor is in most cases much below the temperature necessary to cause combustion.

For all liquids the volatility increases with rise of temperature. For any liquid there corresponds a temperature at atmospheric pressure below which the liquid will not pass into vapor in dangerous quantity, and consequently this temperature becomes a dividing line above which a flammable or explosive mixture may be formed with the surrounding air by the vapor from the liquid. It is of primary importance, therefore, in classifying the hazards of a liquid to determine this temperature.

When a liquid is heated in a closed space such as a cylinder, the pressure within the space rises. As the pressure corresponding to a given temperature will depend upon the volatility of the liquid, it is necessary to have a measure

*Note—It is recognized that under normal conditions where the vapor of the liquid is admixed with air the vapor pressure is somewhat different from that in the isolated liquid-vapor, and that the evaporation of a liquid is influenced by other factors than the vapor pressure. Nevertheless the tendency to assume the vapor state is indicated sufficiently accurately for our purpose by the vapor pressure test.

of its vapor pressure in determining the type of container required for its safe use and storage.

For the foregoing reasons it is our practice in classifying the hazards of a liquid to determine its volatility with reference to both *temperature* and *pressure* in order first, to establish the dividing line with reference to the ordinary temperature above which the liquid will give off flammable vapor in dangerous quantity, and second, to ascertain its vapor pressure at 20° C. (68° F.) and at other temperatures when necessary.

There are several laboratory test methods available for measuring the volatility of liquids in respect to temperature, and in terms of pressure.

The flash point test* (Closed Cup) is employed when possible in the case of liquids of both high and low volatility to obtain data primarily with reference to the approximate temperature at which vapor is given off by a liquid in sufficient quantity to form flammable mixtures with the surrounding air. The flash point test,** however, cannot in all cases be depended upon in this respect. The flash point is influenced materially by the type of apparatus, and the test procedure employed. Even when a standard form of apparatus is used, the presence of certain volatile ingredients in the liquid such as carbon tetrachloride may not only raise the flash point above its true value, but may mask it. It is our practice to supplement the flash test with other volatility tests as well as with flame propagation tests in an explosion chamber of appropriate dimensions.

In the case of the more volatile liquids of the class that can be converted into vapor by heat without decomposition, a static method using Hoffmann's well-known vapor density apparatus is employed to determine the vapor pressure.

A fractional evaporation or distillation test is also sometimes necessary in order to differentiate between fractions of a mixture containing ingredients of different hazard and volatility. In the case of oils of low volatility, a simple evaporation test in an oven will usually give the required test data.

Ignition Temperature.

If vapor is given off by a liquid in sufficient quantity to form a flammable mixture with the surrounding air, it is important to determine its apparent ignition temperature. By apparent ignition temperature, as will be more fully explained later, is here meant the lowest temperature to which any part of a vapor or gas-air mixture must be raised by the application of heat to produce combustion that will propagate itself.

The external source of heat necessary to ignite the vapor may be in the form of a flame, spark, or hot surface. As the temperature of flames and sparks is

*Note—The Flash Point Method and apparatus specified in the Standards of the American Society for Testing Materials are used, except in the case of liquids flashing at temperatures below zero F. (—18.3° C.) when a special form of apparatus is employed.

**Note—The flash test has been advocated as a complete measure of the fire hazard of a liquid. Other limitations of the flash point test are referred to later on in this article.

considerably above the ignition temperature of flammable vapors, it is common knowledge that a fire may be caused by them if exposed to flame or sparks. It is important to also note in this connection that the temperature of ignition of a large number of vapors is below a red heat. In the case of some vapors a moderately hot surface may cause ignition.

In a vessel ignition of a vapor in air may be obtained at a lower temperature than when a heated surface in the form of a wire or bar is employed. Inside of a vessel the area of contact between the vapor and hot surface is comparatively large, and the vapor may undergo oxidation or partial combustion with the evolution of heat, as a result of which the reaction may become self-heating (autogenous) during a short period of time (termed the lag) preceding ultimate ignition. Under certain conditions, particularly in a vessel, the heat evolved by the reaction itself during "the lag" or pre-ignition period may raise the temperature of the mixture above that of the external source of heat. When exposed to a hot surface in the form of a wire or bar, motion of the vapor is produced by convection currents caused by the heat with the consequence that the duration of contact of any layer of the vapor with the surface of the wire or bar is very short, and under these conditions, the vapor may not be heated to ignition unless the temperature of the wire or bar is very high.

There are a number of other factors such as the catalytic and other action of the surface of the source of heat, surface combustion, and initial pressure which influence the ignition temperature, but it is not within the scope of this article to attempt to cover fully the various phases of ignition. The object of our method of test* is to determine the lowest temperature likely to cause ignition of a combustible vapor or other substance in air under conditions that may be met with in service. This temperature as determined by our method, and which for the past sixteen years we have termed the "apparent ignition temperature," is often lower than the actual temperature of the vapor at ignition, but is of more importance from the fire prevention viewpoint than any theoretical value. The "apparent ignition temperature" is of great value for comparative purposes, and in indicating dangerous temperature limits of exposure, particularly in industrial operations.

Flammable Limits.

In the case of most flammable† liquids there is a minimum concentration of vapor in air (oxygen) below which propagation of flames does not occur on contact with a source of ignition. There is also a maximum proportion of vapor in air beyond which combustion does not occur. In other words, there

*Note—This method has been tentatively adopted by the American Society for Testing Materials. For description see report of Committee D-2 on Petroleum Products in Proceedings of the thirty-first annual meeting of this Society.

†Note—Most combustible substances do not burn or explode when heated to their ignition temperature except in the presence of air (oxygen). There are, however, some substances which under certain conditions decompose with the production of heat and light without the presence of air (oxygen). This class is referred to later in the discussion on chemical stability.

is a minimum concentration not only of vapor, but of air necessary for the propagation of flame. These minimum and maximum concentrations of vapor in air which if ignited will propagate flame are known as the lower and higher flammable or explosive limits, and are usually expressed in terms of percentage of vapor in air by volume. These limits differ to a marked degree in the case of different liquids. Between the lower and higher limits there is a concentration that will produce the most intense combustion or explosion of which the vapor is capable. Readers who have attempted to adjust the carburetors on automobiles will appreciate that there is a lower and higher limit to the ratio of vapor to air which can be ignited by the spark plug, and that an adjustment, giving a mixture which is neither too thin nor too rich in vapor of gasoline, is necessary to obtain the maximum explosive power.

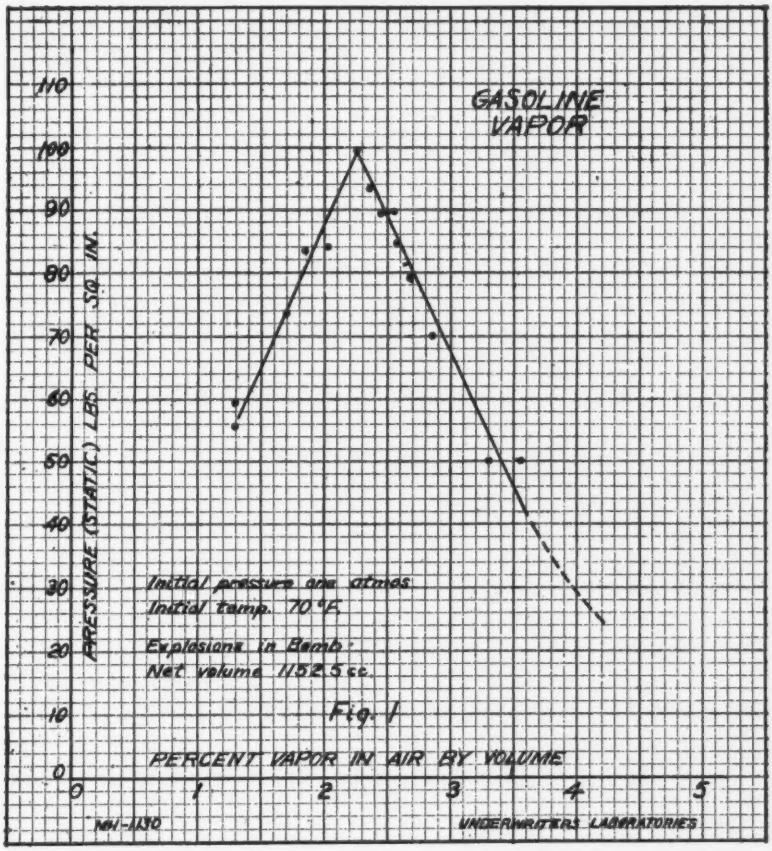
The difference between the low and high flammable or explosive limits of a vapor is known as the flammable or explosive range. For example, the lower flammable limit of gasoline is approximately 1.4 (per cent of vapor in air by volume) while the higher or upper limit is about 6, and by difference the flammable or explosive range is 4.6.

It will be noted that no attempt has been made to differentiate between the terms flammable and explosive as applied to the lower and upper limits. In the case of most vapors and gases there is no basis for a sharp distinction between flammable limits and explosive limits as one is in general disposed to imagine. The propagation of flame in commonly known vapor of gas-air mixtures is relatively slow in the initial stages. Where the mixture is only partially confined a slow and "uniform speed" of propagation first occurs over a limited distance from the point of ignition. This initial phase of flame propagation which may be regarded as progressive combustion may be followed under certain conditions by a marked acceleration of speed together with an undulatory movement, which may result in vibrations. This is the phase of flame propagation commonly recognized as an explosion. There is a third phase in the propagation of flame termed the detonation wave, or simply, detonation* which in the case of many vapors and gases may be set up, depending upon the conditions. Any of these phases of flame propagation under conditions of confinement will produce a pressure rise. The ultimate result will depend upon the nature of the vapor, particularly its "combustion intensity," and the conditions, such as the proportions of vapor in air, the dimensions and strength of the container.

The relation of the explosion pressure (static) to the percentage of gasoline vapor in air is shown in the curve** Fig. 1.

*Note—It is not within the scope of this article to fully present the different phases of flame propagation that have a bearing on the fire and explosion hazard.

**Note—The upper limit of gasoline vapor is not covered by this curve.



The curves showing the relation of explosion pressure to ratio of vapor to air in the case of other common liquids are of the general form shown, although the flammable limits vary considerably, as shown in Table I (next page).

When a flammable liquid is exposed to the surrounding air, the lower limit determines the minimum amount of vapor necessary to produce a unit volume of flammable mixture. Evidently, then, the lower the low limit the more hazardous is the vapor or gas, other factors being assumed to be equal.

The upper limit and the flammable range also have a bearing on the fire hazard. It has been shown by experience that a relatively narrow flammable range, if in conjunction with a comparatively low lower limit, may constitute a marked fire hazard, as in the case of gasoline, although in general the wider the flammable range the greater the hazard in this respect.

Table I.

	Lower Limit by Volume	Upper Limit by Volume	Range
[n]Gasoline	1.4	6	4.6
[c]Ether (Ethyl)	1.9	22	20.1
†Carbon Disulphide	1.0	50	49.0
[i]Benzene	1.5	8	6.6
Ethyl Alcohol	3.5[s]	19[n]	15.5
†Carbon Monoxide	12.5	74	69.9
[v]Illuminating Gas	5 to 7	21 to 31	14 to 26
[a]Ammonia (NH_3)	16	25	9
[a]Hydrocyanic Acid	5.6	40	38.4

c—Coward, Carpenter, and Paymen.
n—Nuckolls, W. K. Munn.
i—International Critical Tables.
†—Coward and Jones, Bureau of Mines. Bul. 279.
a—Nuckolls, Matson, and W. T. Wright.
s—Selected from literature on subject.
v—Composition varies to some extent.

It may be well at this stage to point out in advance that although the hazard of a liquid is determined by its properties, any particular phase of hazard is not directly proportional to the corresponding hazardous property; in other words, the individual hazards of a liquid are not straight-line functions of the corresponding hazardous properties, as will be explained later under the second section of this paper on the relationship of the hazardous properties to the fire hazard as determined by our method of classification.

The flammable limits are influenced by the initial temperature, the dimensions of the container, and the pressure. It has been shown* that the lower limits are reduced somewhat in certain cases by turbulence.

Theoretically, the lower limit will be decreased and the upper limit increased, and therefore the flammable range widened by rise of the initial temperature. It appears from available experimental data that this is in general true. Tests[m] at the Laboratories show that the lower limit of gasoline is approximately 1.1 at 100° C. (212° F.).

A narrowing of the range is caused by a reduction in pressure below atmospheric. In tests** at the Laboratories with gasoline using electric discharge as a source of ignition at 200 mm. of mercury (absolute) pressure (22 in. vacuum) the lower and upper limits have been found to be approximately 1.5 and 2.6. Pressures above atmospheric† do not appear to have much influence on the limits of flammability.

The normal variations of atmospheric pressure and temperature have practically no influence on the limits of flammability.

*Note—Coward and Jones, Bureau of Mines Bulletin 279.

[m]Note—A. F. Matson and D. T. Wright.

**Note—D. T. Wright, A. F. Matson, and the writer. Propagation of flame was observed at pressures as low as 50 mm. of mercury (absolute) using a hot wire as a source of ignition.

†Note—Tests by the writer (Rpt. Underwriters' Laboratories, 1920) on limits of mixtures of hydrogen and oxygen indicated that the lower limit of hydrogen in oxygen was not materially changed by increase of pressure to 122 atms.

The dimensions of the vessel, particularly its diameter when within certain limits, influence the flammable limits, and it is therefore our practice to conduct such tests in vessels of different dimensions.

Combustion Intensity.

Having determined the volatility of a liquid, the ignition temperature of its vapor, and its flammable limits, together with the concentration of vapor in air which will give the most intense combustion of which the vapor is capable, the next important step is to obtain data on the intensity of combustion of the vapor as compared with that of vapors of other flammable liquids, particularly those of well-known liquids, the hazards of which have been established by experience.

The combustion intensity of a liquid depends upon a number of factors, including its heat of combustion, heat of vaporization, and how fast the chemical action (combustion) goes.

It is a matter of common knowledge that the chemical reaction known as combustion is attended by the evolution of heat. The amount of heat development accompanying the combustion of unit mass of a given substance is known as its heat of combustion. The heat of combustion is susceptible of measurement, and is recorded in terms of a unit quantity known as the (gram) calorie, which is the amount of heat required to raise the temperature of one gram of water one degree* Centigrade. In place of the gram calorie the B. T. U., which is the amount of heat required to raise one pound of water one degree Fahrenheit, is often used.

The heat of combustion of a given substance is always the same, if the conditions of the chemical reaction are the same, regardless of whether the combustion takes place slowly or rapidly or occurs in air or in pure oxygen. The difference in the temperature effect between slow and rapid combustion of substances is primarily in the length of time during which the heat of combustion is evolved. In both slow and rapid combustion heat is rejected to external systems, but in slow combustion the heat exchange with external systems by thermal conduction, convection, and radiation results in a wider distribution of the heat units, and consequently in spite of differences in heats of combustion of ordinary combustibles, the temperature effect is less than in the case of rapid combustion. In the absence of other factors capable of affecting the result, we may regard the temperature as depending upon the number of calories evolved in unit time.

It is a fact that the intensity of combustion frequently goes hand in hand with heat of combustion; nevertheless, the heat of combustion of a substance is not a measure of its chemical affinity, its rate of reaction, or the readiness with which its combustion takes place.

*Note—More accurately from 15.5 to 16.5° C. The larger calorie, known as the Kilogram Calorie, is equal to 1000 small calories.

In Table II following, data on the heat of combustion of a number of well-known gases and vapors are given.

From the Law of Avogadro, we know that the volumes occupied by the molecular weights of all gases under like conditions of temperature and pressure are the same. Hence, the heat of combustion expressed in terms of gram molecules gives the heat of combustion of equal volumes of different gases and vapors as shown in the second column of the Table. Knowing the percentages by volume in air of various gases and vapors required for complete combustion, the heat of combustion of unit volume of different gas or vapor-air mixtures can be calculated, and is shown in column three of the Table. It will be observed that there is a general parallelism between the amount of heat evolved or the heat of combustion of gases and vapors and their intensity of combustion. It is evident, however, that the combustion intensity is not determined by the heat of combustion alone, as comparison of the values given in the Table for acetic acid, hydrogen, and carbon disulphide will show.

Table II—Heat of Combustion.

Products of Combustion, CO_2 or SO_2 and Water in State of Vapor.

Substance	Kilogram Calories	Kilogram Calories Per Gram Molecule	Kilogram Calories Per Cubic Foot of Mixture of Gas or Vapor with Air*
Acetic Acid—CH_3COOH			
CH_3COOH (vapor)$+2O_2=2CO_2+2H_2O$...	3,395.4[b]	203.863	22.82
Acetone—$(CH_3)_2CO$			
$(CH_3)_2CO$ (vapor)$+4O_2=3CO_2+3H_2O$...	6,969.9[b]	404.673	23.75
Acetylene—C_2H_2			
$C_2H_2+2\frac{1}{2}O_2=2CO_2+H_2O$	11,560.1[a]	300.911	27.61
Benzene—C_6H_6			
$C_6H_6+7\frac{1}{2}O_2=6CO_2+3H_2O$	9,676.1[a]	755.511	24.30
Carbon Disulphide—CS_2			
CS_2 (vapor)$+3O_2=CO_2+2SO_2$.....	3,320.3[b]	252.776	19.37
Carbon Monoxide—CO			
$CO+\frac{1}{2}O_2=CO_2$	2,412.9[a]	67.561	23.68
Ethane—C_2H_6			
$C_2H_6+3\frac{1}{2}O_2=2CO_2+3H_2O$	11,239.4[a]	339.361	22.73
Ethyl Alcohol—C_2H_5OH			
C_2H_5OH (vapor)$+3O_2=2CO_2+3H_2O$.....	6,681.7[b]	307.760	23.72
Ethylene—C_2H_4			
$C_2H_4+3O_2=2CO_2+2H_2O$	11,399.8[a]	319.650	24.73
Ethyl Ether—$(C_2H_5)_2O$			
$(C_2H_5)_2O+6O_2=4CO_2+5H_2O$	8,499.1[b]	629.788	25.05
Gasoline—Vapor	10,500.0	1065.4[c]	25.5[c]
Hydrogen—H_2			
$H_2+\frac{1}{2}O_2=H_2O$	28,386.4[a]	57.227	20.05
Kerosene—Vapor	11,500.0	.....	....
Methane—CH_4			
$CH_4+2O_2=CO_2+2H_2O$	11,981.0[a]	192.177	21.63

Note—Constant volume values selected from University of Illinois Bulletin No. 139 and the available literature on the subject.

*In combining proportions.

[a]Temperature 62° F. (16.6° C.).

[b]Temperature 64.4° F. (18.0° C.).

[c]Based on tests of ordinary gasoline having a mean vapor density 3.5 (Air=1).

The speed of combustion of substances in the solid state is influenced by the form in which they exist at the time of ignition. In the case of flammable liquids the most rapid combustion occurs when they are in the form of vapor in certain proportions with air at the time of exposure to ignition as previously mentioned under Flammable Limits. If the liquid is in an open tank or other vessel, and its initial temperature at the time of exposure to ignition is above the temperature-dividing line or flash point above which flammable vapor is evolved, as soon as most of the accumulated vapor above the liquid has burned, the speed of subsequent combustion will diminish, depending upon a number of factors, including the heat of vaporization and the volatility of the liquid.

From the foregoing it is obviously important to determine the comparative rapidity of combustion of a liquid together with its temperature effect under conditions comparable with those met with in practice. In our method of classification of liquids all these phases of the combustion hazard are included under combustion intensity.

No single laboratory test method is at the present time available for directly determining the combustion intensity of a liquid, and it is necessary to resort to a combination of methods.

It is therefore our practice in determining the combustion intensity of a liquid to obtain data on its speed of combustion under conditions; first, when the liquid is in the form of vapor in certain proportions with air, and second, when the liquid is exposed to ignition in an open vessel. These data taken in connection with the comparative heat effect of the liquid during combustion are sufficient for purposes of classification of this phase of its fire hazard.

Hazards by Combination.

The foregoing properties may be regarded as having to do primarily with the hazards of flammable liquids by combination (combustion) with air (oxygen). We have now to consider the hazards of liquids by combination with other substances commonly met with in practice.

The danger of fires being caused by the reactions of water with sodium, potassium, quicklime, strong sulphuric acid, certain metallic powders and carbides, particularly calcium carbide, is well known. Fires have been caused by the action of concentrated nitric acid on organic substances, including wood, turpentine, etc.

It is fortunate that the petroleum products such as gasoline and kerosene are relatively stable chemically and relatively inert in respect to their ability to cause heating or ignition by contact with ordinary substances.

It is our practice to conduct a study of the chemical properties of a liquid to determine its tendency, if any, to react with common substances, and to call attention in our listing to any dangerous tendency to react with common substances, including water, mineral acids, nitrates, and organic materials such as grains, textiles, wood, paper, etc.

No attempt is made to include in our classification of the hazards of liquids any evaluation of this phase of the hazard, it being deemed sufficient for the purpose to mention any outstanding danger in this connection for the information of inspection authorities.

Vapor Density.

By vapor density is meant the weight of a given volume of vapor as compared with the weight of an equal volume of air under similar conditions as to temperature and pressure. The vapor density of a flammable liquid in conjunction with its rate of vapor diffusion with the surrounding air plays an important part in the formation of flammable or explosive mixtures.

As the velocity of diffusion of a gas or vapor is inversely proportional to the square root of its density, the light vapors diffuse or intermix with the air much more rapidly than the heavy ones. If the vapor given off by a liquid has a density less than that of air, it will have a tendency to ascend, and to intermix comparatively rapidly with the air; on the other hand, relatively heavy vapors will tend to descend, and to diffuse or intermix with air very slowly.

Gases or vapors of different density when confined in the same space will form a uniform mixture, if given sufficient time, but under ordinary conditions the rate of mixing of heavy vapors such as those of gasoline and carbon disulphide with air is comparatively small, with the consequence that if there are no draughts in a room where a heavy vapor is given off by a liquid a low stratum of vapor may be temporarily formed. At the interface between the stratum of vapor and air a flammable mixture will exist, and the depth of this flammable mixture will gradually increase as the vapor diffuses with the air. In low places pockets of heavy vapor may be formed and remain for some time. A stream of heavy flammable vapor such as that of gasoline may under certain circumstances flow to a distant source of ignition such as a lamp or open fire, and propagate flame back.

In Table III below the relative density of a number of flammable gases and vapors is given.

Table III.

Gas or Vapor	Approximate Vapor or Gas Density Air=1
Hydrogen	0.069
Carbon Monoxide	0.96
Alcohol, Methyl	1.1
Alcohol, Ethyl	1.6
Acetone	2.0
Ether, Ethyl	2.6
Carbon Disulphide	2.6
Benzene	2.7
Gasoline	*3.5
Kerosene	*4.5

*Note—These are mean values for gasoline and kerosene found in common use.

Nature of Products of Combustion.

When the vapors of most flammable liquids are burned completely in the air the products of combustion are water vapor and carbon dioxide. The water is produced by the combination of hydrogen, which is a common constituent of most volatile combustibles, with the oxygen of the air, and the carbon dioxide by combination of carbon, which is also a common constituent of most combustibles, with the oxygen of the air. The inert constituents of the air, nitrogen and argon (in small quantity), are also found mixed with the products of combustion.

Under ordinary fire conditions the burning of most flammable liquids is incomplete, thus producing, in addition to carbon dioxide and water vapor, smoke, *carbon monoxide,* the dangers of which are well known, and other products. Carbon dioxide and water vapor are dissociated at high temperatures into oxygen, carbon monoxide and hydrogen. The question as to whether the chemical reactions involved in the combustion of a vapor in air go to completion or stop in an intermediate stage, depends upon the conditions (equilibrium). The driving force of the chemical reaction is influenced by the changing concentration of vapor and air in the reacting mixture. As the equilibrium condition is approached, the driving force decreases. Temperature is the governing factor in determining these conditions. Directing our point of view to ordinary fires where there are no laboratory conditions of control, it will be clear that there exist at any moment a number of zones of combustion, evidently differing from each other in air-fuel ratio, reaction velocity and temperature, and consequently in respect to the products of combustion.

The products of combustion of most flammable liquids are comparatively harmless with the exception of carbon monoxide. As pointed out above, the ratio of carbon monoxide to carbon dioxide and to other products of combustion will in general depend upon the fire conditions, rather than on the composition of the liquid.

There are liquids, however, the combustion of which under ordinary fire conditions produces excessive amounts of smoke and even noxious or irritating gases, which may seriously impede workers in extinguishing fires. Carbon disulphide, for example, burns to carbon dioxide and sulphur dioxide. From the reaction $CS_2+3O_2=CO_2+2SO_2$ it will be noted that the combustion of one volume of this vapor produces one volume of carbon dioxide and two volumes of sulphur dioxide, the latter an irritant gas.

It is our practice in classifying the hazards of a liquid to obtain information as to its products of combustion under ordinary fire conditions, and to call attention in our report and listing to any noxious or irritant product of combustion, or any tendency to produce an excessive amount of smoke. No attempt is made, however, to include these items in the hazardous rating, as will be explained later.

Toxicity.

Under this heading are included flammable liquids which act upon the human body as poisons, asphyxiants, anesthetics, and irritants, or in any way to seriously impede in the work of extinguishing fires.

The toxicity of a liquid or vapor is considered as having an indirect bearing on the fire hazard in either or both of the following ways: first, it may by contact with the skin or through inhalation act upon the body in such a way as to rapidly incapacitate or drive away workers and thereby introduce a serious hazard in case of a fire; second, it may in case of fire, particularly if water-soluble, be carried by water, employed in an effort to extinguish the fire, to food products which may be stored in an adjoining part of the building.

It is our practice in listing a flammable liquid to make reference to any of its toxical properties considered to be of importance from the fire prevention standpoint on the basis of the information obtained from the literature and our experience. Although the toxicity of a liquid has an indirect bearing on the fire hazard, no attempt is made in our method of classification to rate it in terms of fire hazard, as will be explained later.

Chemical Stability.

In determining the hazards of a liquid by laboratory tests, the question arises as to the stability or permanency of its properties under certain conditions of exposure that may be encountered in its use and storage. A liquid which is chemically unstable under conditions of use may undergo changes resulting in the evolution of heat or the formation of a more hazardous product. The tendency of a liquid such as linseed oil to combine at ordinary temperatures with the oxygen of the air (oxidize) with evolution of heat may become a factor in causing (spontaneous) ignition.

In most cases of combustion the substance or a portion of it is first heated to its ignition point by the application of external heat. However, under certain conditions the ignition of some substances may occur without the application of sufficient external heat to raise them to their ignition temperature. In such cases the substance, through physical or chemical changes taking place in the substance itself or through chemical reactions between the constituents of the substance and the air, becomes heated to its ignition point (spontaneous ignition).

In a broad sense no flammable liquid or any other substance is chemically stable with respect to all possible processes, but in a sound method of classification of hazards we must determine if the liquid is in a stable state with reference to the changes of state such as freezing, boiling, etc., to which it may be subjected under its normal conditions of use and storage; otherwise dynamic or potential processes of change in its hazardous properties may not be brought to light, and a false sense of security as to the status of its hazard may be made possible.

A liquid may be in a stationary or stable state because its composition corresponds to a state of equilibrium from which it has no tendency to depart (true stability); or it may be in a stationary state because its ingredients are inert or so unreactive that any processes of change are too slow to be observed. By chemical stability of a liquid as applied to our method of classification is meant a stationary chemical state in which the hazardous properties as experimentally determined do not undergo observable change under normal conditions of use and storage.

A substance capable of undergoing spontaneous *decomposition* with evolution of heat so that the process accelerates itself after once starting belongs at least potentially to the explosive class. It is important therefore to distinguish between two classes of substances known respectively as *exothermic* and *endothermic* compounds. Compounds formed from their elements with evolution of heat are termed exothermic in contradistinction to compounds formed from their elements with absorption of heat.

The bulk of compounds met with in practice are exothermic and, in general, relatively stable chemically. Endothermic compounds evolve heat on decomposition, and are as a rule comparatively unstable. When an endothermic substance is burned in the air there is an evolution of heat corresponding to the decomposition (heat absorbed in formation) in addition to the heat of combustion due to its elements. Certain endothermic substances may therefore by decomposition evolve sufficient heat even in the absence of air (oxygen) to produce a fire or an explosion. Examples of endothermic compounds are acetylene,* carbon disulphide, which can be decomposed by shock, and azoimide, which is highly explosive.

The comparative stability of a liquid in respect to the processes met with under ordinary conditions can be determined by tests of its reactions with certain reagents, and frequently by a study of its chemical constitution and properties.

Relation of Hazardous Properties to Fire Hazard.

Field experience is the best criterion for evaluating the fire hazard of a liquid or any other substance, provided it extends over a long enough period of time to include the dangerous effects of all the important factors that may be met with in practice. Obviously there are many variables, including the rôle the human element plays, that operate in bringing about the exposure of a substance to sources of ignition and other effects of the different factors under various conditions favorable to the development of its inherent hazards. Where the time factor is inadequate, particularly in the case of a substance having a limited commercial use, the effects of certain factors capable of bringing to light serious hazardous properties may not be observed. It is

*Note—While acetylene gas under high pressure is dangerous, it may be used with comparative safety under the established regulations of the National Fire Protection Association.

sometimes difficult to determine from field records or by statistical methods whether or not this time factor in the field experience on any substance is adequate. There is a need, therefore, for methods of test for determining the fire hazards of substances and systems without waiting to obtain the record of field experience.

In this age of rapid progress in the manufacture and introduction of new chemical compounds and processes, together with high speed equipment operating at higher electrical potentials and gaseous pressures than those heretofore employed in industry, new phases of fire hazard are presented on which no adequate field data are available. In such cases the advantages of a method for determining hazards by laboratory tests under conditions of control are twofold: to discount the time factor required for adequate field experience, and to prevent the possible loss of lives and property incident thereto.

Field experience is our primary source of knowledge of fire hazards, and any sound system of tests, the results of which are to be employed as a criterion for classifying the fire hazard of liquids or any other substances, must take cognizance of the *effects* of the hazardous factors developed by field experience. It is not necessary nor usually feasible to reproduce in laboratory tests all the conditions under which these *variables* operate in practice, but the essential *effects* in causing and promoting fires should be determined and applied.

The various and direct causes or sources of ignition involved in field experience can be resolved into sparks, flames, heated surfaces and bodies which ignite on contact with certain substances. The indirect sources of ignition can be resolved into temperature and pressure conditions which promote physical and chemical processes that may cause ignition. The temperature, together with the heat capacity of any system of variables, and often also the air supply, are important elements in all these sources of ignition. The normal variations of atmospheric pressure have practically no influence on the hazards, but in many industrial operations the variations in pressure *are* sufficient to affect the fire hazard of liquids. In general, a decided reduction in pressure below that of the atmosphere increases the volatility of a liquid but reduces the hazard of its vapor, while a rise in pressure increases the hazard of the vapor. The effects of pressure on the hazard of all liquids of the exothermic class are comparatively the same, and it is not therefore necessary in our method of classification to differentiate the hazard of liquids on the basis of external pressure changes. Dangerous endothermic liquids are noted in the listing.

It will be observed in this connection that in our method the properties of liquids are differentiated with reference to their *minimum* temperature of ignition under conditions comparable with those in the field (apparent ignition point), their temperature of volatilization with reference to the ordinary tem-

perature (volatility), their reactions by contact with common substances (hazards by combination), their hazardous changes under conditions of use and storage (stability), their comparative combustibility under practical conditions (intensity of combustion and limits of flammability). In addition, the hazardous behavior of the vapor with respect to certain practical conditions is determined (vapor density). Their toxicity and products of combustion in relation to fire hazard are included.

Theoretically, it would be desirable for test purposes to resolve the field variables, such as the sources of ignition, into simple terms of temperature and heat capacity, which would greatly simplify the problems of testing for hazards, but it appears that our present knowledge of combustion has not been advanced to this degree. In determining the reaction of liquids to the sources of ignition involved in field experience, for example, our test procedure must include not only temperature in conjunction with heat capacity, but other factors such as the influence of surfaces (catalysis), ionization.

While the hazardous properties of liquids are determined by this method with reference to our knowledge of the effects of the variables of field experience, no attempt is made to differentiate their hazards on the basis of the mathematical probability of the frequency of exposure of any particular liquid, by virtue of its intended commercial use, to any of these variables. The chance of the occurrence of events leading to the exposure of a liquid or any other substance to any source of ignition or variable of field experience is a phase of fire hazard that varies with circumstances and current practices, and is often so complex as to elude analysis.

It is important in this connection to distinguish between the inherent hazards of a liquid, and hazardous situations or conditions of exposure existing in any particular instance. The different conditions under which liquids are employed commercially and domestically involve different exposure factors. Gasoline, for example, when used under conditions of control by persons familiar with the precautions necessary in handling it to prevent fire, may cause no trouble, but on the other hand, this same gasoline in the hands of users not familiar with its hazards, or who think it is kerosene, may cause a serious loss. In the Laboratories' method the inherent hazardous properties of liquids are brought to light and given a comparative classification to serve as a basis for determination by inspection authorities of matters relating to hazardous situations or hazardous conditions of exposure in the field.

In connection with the relation of the hazardous properties of liquids to the fire hazard, the question is often raised as to whether or not these properties cannot be expressed in more fundamental terms. There is in general a relation of chemical and physical properties of substances to their chemical composition and constitution, and theoretically it would therefore be desirable to differentiate the individual hazards or properties of liquids in terms of more

fundamental physico-chemical data, which would be applicable in deducing the fire hazard. Some attempts have been made to relate certain hazardous properties such as ignition temperature, limits of flammability, etc., to more fundamental chemical and physical characteristics, but very little progress has been made in this direction. Combustion and flame propagation is a far more complex process than has been generally realized, and many of the theoretical problems relating thereto have not been solved. Therefore, in the light of our present knowledge of combustion, the hazardous properties of liquids cannot as yet be resolved into terms of "fundamental data."

Flash Point Alone Not a Satisfactory Measure of Hazard.

We are often asked whether or not the flash point alone is a satisfactory measure of the fire hazard of a liquid. In general the flash point test is one of the most useful tests known for determining the temperature at which a liquid evolves flammable vapor in dangerous quantity. It has been the trade custom for many years, particularly in the petroleum industry, to regard the flash test as a criterion of fire hazard. Many municipalities, states, and countries have established flash point requirements for kerosene, but there are wide variations in these requirements as to what particular temperature limit insures safety. In the literature many writers differ from each other in their definitions of flash point. Various methods of conducting the flash point test are advocated, and values reported by different workers are not in many cases in agreement.

An analysis of the various forms of apparatus and methods employed in conducting the flash point shows that the essential parts are (1) a *cup* or container for the liquid to be tested, (2) a heater, (3) a small testing flame or sparking device, and (4) a thermometer with which to measure the temperature of the liquid. The test procedure consists essentially in raising the temperature of the liquid in the *cup* by means of the *heater*, while introducing the *testing flame* into the air space in the cup above the liquid until a flash occurs. The temperature of the liquid at the time the flash is observed is recorded as the flash point. The variations in the different forms of apparatus relate to the type of heater; the nature and dimensions of the test flame; the type of thermometer; the shape and dimensions of the cup, and in having it open to the air (open cup) or covered (closed cup); in the latter case an opening is provided in the cover for introduction of the testing flame which is controlled manually or automatically. The methods of procedure differ essentially in respect to the rate of heating the liquid and the frequency of application of the test flame. In some forms of apparatus the test flame is automatically applied.

It will be observed from the foregoing that whatever the form of flash point apparatus or test procedure employed, the essential information obtained by the test is the temperature at which the liquid in the cup evaporates fast enough to form a vapor-air mixture which will take fire (flash) when the test

Table IV.

Liquid	Flash Point (Closed Cup) Deg. F.	Apparent Ignition Point Deg. F.	Vapor Density Air=1	Chemical Stability	Combustion Intensity	Limits of Flammability by Vol. Lower	Upper
Acetic Acid	106.7	800–925	2.	Comparatively stable	Exceedingly low		
Benzaldehyde	148	377	..	Comparatively stable		..	..
Carbon Disulphide	—22**	...	2.6	Endothermic	High	1.0	50
Ether	—49	356	2.6	Comparatively stable	High	1.9	22
Gasoline	—45** to 0†	536	3.5	Comparatively stable	High	1.4	6
Kerosene	100	482	4.5	Comparatively stable	High	..	..
Linseed Oil (Raw)	431	746	..	Subject to spontaneous ignition*	High	..	..
Cotton Seed Oil	485	761	..	Subject to spontaneous ignition*	High	..	..
Paraffin Oil	444	...	..	Comparatively stable	High	..	..

*Note—Cotton seed and linseed oils oxidize on exposure to the air and cause spontaneous ignition under favorable conditions.

†Note—Samples of gasolines obtained on the open market over a period of several years yielded flash points ranging from —45 to 0° F.

**Note—Nuckolls (1910).

flame is applied. The flash point therefore shows whether or not the vapor of the liquid is combustible in the presence of air at atmospheric pressure, and depends upon the volatility of the liquid, and also upon the presence or absence of other volatile constituents which may or may not mask the flash as previously mentioned. Other limitations of the flash point are discussed below.

The flash point alone is not a measure of the fire hazard of a liquid in respect to its ignition point,* flammable limits, hazards by combination, vapor density, toxicity, and chemical stability. It fails to differentiate between liquids of the exothermic and endothermic class. It does not reveal a tendency of a liquid to spontaneous ignition.

In conducting the flash test a rough estimate may be made by an experienced observer as to the comparative rapidity of combustion of the vapor in the small cup, but other tests are required to obtain reliable information on the intensity of combustion of the vapor of the liquid. It is also possible for an observer to detect certain noxious products of combustion while conducting the flash test. In Table IV certain hazardous properties of a few liquids, including their flash points, are given. It will be evident on inspection of the data that while there is in many cases a general parallelism between liquids having

*It is recognized that the flash point of a liquid indicates that its ignition point must be above the flash temperature, and below the temperature of the testing flame. The temperature of testing flames is, however, high (white heat). Other tests must be resorted to in order to learn whether or not the liquid will ignite at dangerously low temperatures.

"low" flash points and those of a hazardous nature, the flash point alone reveals only the volatility hazard.

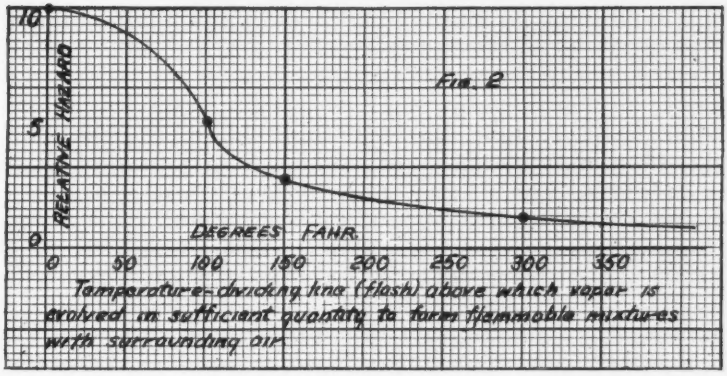
The relation of the hazardous properties of liquids to fire hazard in general has been made evident in a qualitative sense in the foregoing discussion. It now remains to establish the quantitative relationship between these properties and the fire hazard.

The Volatility Hazard.

We have seen that for any given flammable liquid there corresponds a temperature dividing line above which vapor is evolved in sufficient quantity to form flammable or explosive mixtures with the surrounding air. Field experience shows that a liquid which evolves flammable vapor at or below the ordinary temperature is more hazardous, all other factors being equal, than one which gives off vapor at higher temperatures, and that as the temperature of evolution of vapor rises the hazard decreases. The hazardous properties of the vapor-air mixture formed will depend upon the ignition temperature of the vapor, its combustion intensity, etc., but for the present let us confine our attention to the volatility hazard, assuming other factors equal.

The relation of the temperature dividing line above which vapor is evolved by a liquid (its flash point) to the fire hazard is not confined to the region of the ordinary temperature, but extends to as high and as low temperatures as are met with in practice. If a flammable liquid is exposed to the air at a temperature above that at which vapor is evolved, the time required to form a flammable or explosive mixture with the surrounding air will depend upon a number of factors, including the dimensions of the enclosure, if any, the quantity of the liquid, the area of the liquid surface exposed to air, the vapor density, the rate of diffusion of the vapor, air currents, if any, and largely the difference between the surrounding temperatures and the temperature at which the liquid evolves vapor. The greater this temperature gradient the faster the evaporation of the liquid, and vice versa. While the relation of the temperature at which a liquid evolves flammable vapors (flash point) to its fire hazard extends to the temperature limits met with in practice, it is quite evident that as these limits are approached the increase or decrease in fire hazard, as the case may be, corresponding to a given increment or decrement in the temperature at which a liquid evolves vapor (flash point), will gradually diminish. In other words, the volatility hazard is not a straight-line function of the temperature of evolution of vapor. The relation of the volatility hazard to the temperature of evolution of vapor (flash point), as represented by the curve in the diagram shown in Fig. 2 (next page), has been employed in our method of classification for many years.

The lower horizontal line (axis) of the diagram is a temperature scale in deg. F., and the vertical line (axis) at the left is a hazard scale. The height of the curve at any point as measured on the vertical axis shows the relative



volatility hazard of any liquid which evolves vapor in dangerous quantity at the corresponding temperature on the horizontal axis.

Beginning at the right side of the diagram, where the temperature is relatively high, it will be observed that as the curve travels to the left approaching the ordinary temperature it becomes steeper; in other words, as the temperature of evolution of vapor approaches the ordinary room temperature each unit decrease in the temperature of evolution of vapor corresponds to an increasingly larger change in the hazard. After the curve has passed through the region of ordinary temperature it rises at a decreasing rate, indicating that in the region below ordinary temperature the hazard continues to rise as the temperature of evolution of vapor falls, but at a constantly decreasing rate.

It would be beyond the scope of this article to attempt to fully analyze the relation of this curve to the fire hazard, and only a brief outline of the basic principles employed in determining its form and application to our method can now be presented.

From considerations brought out in the preceding discussion, it is obvious that the curve in the regions of both the upper and lower temperature limits of the fire hazard is nearly that of a straight horizontal line having very little slope; and conversely, as the curve approaches the ordinary temperature zone its slope must continuously change, becoming steeper. Study of the variations of temperatures met with in practice shows that the ordinary temperature is a variable covering a range or zone of temperature which extends somewhat above and below ordinary room temperature. As the temperature limits of the zone of ordinary temperature vary, it is necessary to choose a point in this region for reference in determining the form of the curve. The general practice of underwriters, based on a long field experience, in regarding 100° F. (temperature of flash) as a dividing line on which to differentiate the volatility hazards of common liquids appears to be the best guide in respect to this phase of the problem. We have therefore selected 100° F. as the reference point in determining the form of the curve at the higher temperature border line of

the zone of the ordinary temperature, and accordingly as the curve approaches this point its slope changes rapidly.

In accord with the conception that the slope of the curve changes at the higher temperature border line of the zone of the ordinary temperature, it is apparent that as the other border line is approached from the opposite direction the slope of the curve must again change. The latter change in the slope is not so sudden, owing to the fact that the increase in hazard with decrease of temperature of evolution of vapor is now more uniform. The form of the curve in the lower temperature region has been determined by a study of the volatility of low flash point liquids, such as ether and gasoline, the hazards of which have been established by field experience.

The hazard scale at the left of the diagram is determined by the volatility in conjunction with certain other hazardous properties of the evolved vapor, as will be explained after the relation of these properties to the fire hazard has been discussed. By way of illustration, carbon tetrachloride is a highly volatile liquid, but its vapor is practically non-flammable and consequently its volatility hazard is zero. If it were endowed with the combustion intensity of gasoline its volatility hazard in conjunction with its combustion intensity could be evaluated.

The ignition temperature of most common liquids, particularly of petroleum products, is considerably above the ordinary temperature, and fires caused by them usually originate from relatively high temperature sources of ignition such as sparks and flames. There are substances, however, such as carbon disulphide, which have ignition points within a range of temperature extending from the zone of the ordinary temperature to the temperature of sparks and flames.

The temperatures produced by steam radiators, boilers, electric light globes, heated surfaces of stoves and other objects are a potential source of ignition to volatile liquids, the vapors of which are capable of igniting within this range of temperature.

The gradient of the ignition point hazard is represented by a curve similar in form to that shown in Fig. 2. The main reference point in the curve is, however, raised from 100° F. to 300° F. on the basis of the temperature range discussed above. As ignition temperatures approach 300° F. there is a decided acceleration of this phase of the hazard. The values employed for the ignition hazard are worked out on the basis of available field experience and data on the ignition of substances at low temperatures.

The curve representing the gradient of the ignition point hazard, while similar in form to the volatility curve (Fig. 2), is independent of it, and serves only as a schedule of the ignition hazard. The relation of the ignition hazard to the total hazard, of course, depends on the volatility, and this relationship is expressed by the volatility curve shown in Fig. 2, as will be explained later.

The gradient of the hazards of the limits of flammability, the explosive range and the combustion intensity, are also measured by curves of the general form shown in Fig. 2. These curves vary somewhat from each other in certain particulars. The test values are plotted on the lower horizontal line (axis). The respective hazard scales represented by the vertical axis are determined with reference to the fire hazard of well-known liquids and gases, such as gasoline, ether, illuminating gas. These relationships in general have been brought out in the preceding discussion of the individual hazardous properties. Following is a brief discussion of the principal critical points employed as gradients of these hazards.

It is shown by field experience data that in the case of the limits of flammability a low limit as high as five per cent may constitute a marked hazard, and that as this value is approached, from say 20 per cent, the increase in hazard is at an accelerated rate. A narrow range together with a low limit, as exemplified in the case of gasoline, may, if the combustion intensity and volatility are both high, constitute a serious hazard.

The lower limit is the main hazard in respect to limits of flammability. As the range (difference between upper and lower limits) widens, the hazard increases, but not at an accelerated rate.

The relation of the limits of flammability, in conjunction with the volatility, to the fire hazard is expressed by the curve shown in Fig. 2. However, it is only when the limits are in conjunction with a high volatility that they require to be treated separately as an integral part of the hazard. In the case of flammable liquids that do not evolve vapor in dangerous quantity at the ordinary temperature, there is no need of evaluating the flammable limit hazard separately. It will be observed in this connection that when a chemically stable liquid which does not evolve vapor at ordinary temperatures is heated the vapor condenses as soon as it passes out of the range of the source of heat, and therefore its flammable limit and vapor density phases of hazard are practically eliminated.

The combustion intensity is evidently an essential phase of the fire hazard of a liquid. A combustion intensity sufficient in degree to readily propagate flame is taken as a basic point on the curve showing the gradient of the combustion intensity hazard. Up to this point the hazard increases at an accelerated rate, and thereafterwards in direct proportion to further increase in the combustion intensity. A comparison of the combustion intensity of acetic acid with that of kerosene in conjunction with their volatility, which is of the same order (flash point 100 and 106° F. respectively), furnishes an example of the importance of combustion intensity as a factor in the fire hazard of a liquid. The volatility curve (Fig. 2) also shows the relation of combustion intensity in conjunction with volatility to the fire hazard.

The vapor density hazard increases at an accelerated rate from one (air=1) to approximately three (gasoline $3\frac{1}{2}$) as shown by field experience

Table V.

Liquid	Purity	Flash Point °C.	Flash Point °F.	Apparent Ignition Temperature °C.	Apparent Ignition Temperature °F.	Classification
1. Acetone	C.P.	—16	3	538-566	1000-1050	Gasoline 90
2. Acetate, Amyl	Pure	25	77	399-427	750- 800	55-60
3. Acetate, Butyl, Normal	C.P.	29	84	371-440	700- 825	
4. Acetate, Ethyl	C.P.	—2	28	427-496	800- 925	
5. Acetate, Methyl	Anhydrous	—10	14	454-496	850- 925	
6. Acetic Acid, Glacial	99.5	42	107	427-496	800- 925	
7. Acetic Anhydride	C.P.	53	127	315-357	600- 675	
8. Alcohol, Amyl (Fusel Oil)	Technical	38	100	371-385	700- 725	Kerosene 40
9. Alcohol, Amyl Sec	Technical	34	94	343-385	650- 725	
10. Alcohol, Amyl Iso	——	45	114	343-385	650- 725	Kerosene 35-40
11. Alcohol, Butyl Iso	106-108° B.P.	31	88	371-427	700- 800	
12. Alcohol, Butyl Normal	116-118° B.P.	38	100	343-385	650- 725	Kerosene
13. Alcohol, Denatured	Formula No. 5	16	61	399-432	750- 810	Ethyl Alcohol
14. Alcohol, Ethyl	Absolute	12	54	371-427	700- 800	70
15. Alcohol, Methyl	C.P.	11	52	427-482	800- 900	
16. Alcohol, Propyl Iso	81.5-82.1° B.P.	16	61	399-454	750- 850	Ethyl Alcohol.....70
17. Alcohol, Propyl Normal	96-98° B.P.	25	77	371-427	700- 800	Amyl Acetate....55-60
18. Aniline	C.P.	84	183	538-607	1000-1025	
19. Aniline, Dimethyl	C.P.	74	165	371-399	700- 750	
20. Benzol	C.P.	—20*	—4*	538-571	1000-1060	Gasoline 95-100
21. Benzaldehyde	C.P.	64	147	192	377	
22. Carbon Disulphide	C.P.	—30	—22	100-106	212- 223	.....110+
23. Cottonseed Oil	——	252	486	343-427	650- 800	Spontaneous Ignition
24. Ether, Ethyl	C.P.	—45	—49	180	356	100
25. Furfural	54-55° B.P./17 mm.	61	143	315-357	600- 675	
26. Gasoline	74-76° A.P.I.	—43	—45	280	536	
27. Glycerine	C.P.	176	350	343-399	650- 750	
28. Hexane	From Petroleum	—26	—15	260-296	500- 565	Gasoline 90-95
29. Lard Oil	——	184	363	343-399	650- 750	
30. Linseed Oil (Boiled)	——	206	403	343-399	650- 750	Spontaneous Ignition
31. Linseed Oil (Raw)	——	222	432	343-399	650- 750	Spontaneous Ignition
32. Methyl Salicylate	U.S.P.	104	219	454-510	850- 950	
33. Nitro Benzene	C.P.	92	198	482-510	900- 950	
34. Olive Oil	——	252	485	343-427	650- 800	Spontaneous Ignition
35. Palm Oil	——	162	323	315-371	600- 700	Spontaneous Ignition
36. Petroleum Ether	40-60° B.P.	—56	—69	329	624	Gasoline 95-100
37. Pyridine	C.P.	23	74	482-593	900-1100	Amyl Acetate
38. Toluene	C.P.	9	48	566-607	1050-1125	75-80
39. O-Toluidine	83-85° B.P./15 mm.	94	202	482-538	900-1000	
40. Xylene	138-139° B.P.	30	86	482-621	900-1150	

*Flash point subject to error of plus or minus 5° C.

data on flammable liquids such as ether, gasoline, and carbon disulphide. There is also a diffusion hazard in the case of vapors and gases lighter than air which increases as the density decreases.

It will now be seen that the primary function of the volatility curve (Fig. 2) is to express graphically the relation of the ignition point, the combustion intensity, and in cases where the volatility is high, the relation of the limits of flammability and vapor density to the fire hazard.

Scale of Hazards.

The scale of hazards applying to each of these individual hazards or hazardous properties has been worked out as described on the basis of available field data on the hazards of well-known liquids. The numerical limits of the volatility scale and of these individual scales are determined with reference to an arbitrary numerical scale of hazard ranging from 0 to 100 plus. The numerical relation of this scale to the fire hazard is determined with reference to the hazards of paraffin oil and ether, the hazards of which are represented by 10 and 100 respectively. In other words, the individual hazards or hazardous properties of ether and paraffin oil when determined by tests and evaluated first by the gradient scales applying to individual hazards, and second, by the volatility hazard scale equal 100 and 10 respectively. When the hazardous properties of kerosene (flash 100° F. closed cup) are worked out on the above basis the hazard equals 40.

In our List a liquid is also classed in respect to fire hazard with some well-known product, the hazards of which have been established by field experience.

No attempt is made to evaluate the hazards incident to toxicity, nature of products of combustion, chemical stability (spontaneous ignition), and hazards by combination. These hazards, when present, are however noted in our listing.

These tests and the classification of the hazards are made only at the request of the manufacturer of the liquid, who is required to file with the Laboratories an application form, together with information as to the nature or composition of the liquid, its intended use, trade name, and type of shipping container. A one gallon sample is usually sufficient for the tests. Pursuant to our usual practice in the testing and listing of materials and devices, the manufacturer is required to accept one of the Laboratories' established forms of supervision over listed products, known as the Re-examination Service, under which samples of the liquid are regularly obtained in the open market or from the manufacturer for subsequent tests one or more times yearly.

In Table V on the opposite page is a tabulation of test data covering a number of flammable liquids. These data include flash point (closed cup), apparent ignition temperature, and in some cases a general classification of hazards.

The Getty No. 17 oil well, Santa Fe Springs, California, burned for fifty-two days before it was extinguished.

Santa Fe Springs Oil Fires.

By Lloyd Griffith, Petroleum Surveyor,
Board of Fire Underwriters of the Pacific (Member N.F.P.A.).

The advance of the science of combating oil well fires has recently been shown by two spectacular fires in the town lot drilling section of Santa Fe Springs, California. Speed in extinguishing such fires is now a secondary consideration to saving the production from the burning wells. Success in this phase of the work makes the recent fires unique in the history of the petroleum industry.

The Getty Oil Well Fire.

After the discovery of the new productive deep oil sands late in July, 1928, the oil companies started a race for production. Among the early starters was Geo. F. Getty, Inc. On September 16th, when drilling had progressed to well over a mile in depth, this company's well, subsequently known as No. 17, blew out of control and almost instantaneously ignited. The initial production was estimated to be from six to ten thousand barrels of oil and from ten to thirty million cubic feet of gas per day. The well burned continuously for fifty-two days, the longest any California well has ever been out of control, with possibly one exception. Yet this well holds the unique record of burning uncontrolled at the mouth of the hole while there was at the same time a recovered production of 8,000,000 cubic feet of gas and 2,500 barrels of exceptionally high gravity crude oil daily. After having been extinguished this crude oil production was increased to nearly 6,000 barrels.

At the time the Getty well "blew in" unexpectedly the race for deep production zones was at its height. The Getty crew was unprepared to cope with the burning gusher they suddenly had on their hands. As the General Petroleum Corporation was the nearest large neighbor their engineers were asked to take charge of the control work.

The first activities consisted of pulling down and removing wooden structures to prevent further spread of the fire, operating sprinkling systems on near-by derricks, placing iron shields to protect combustible structures, throwing up earth dykes completely encircling the burning well, and setting salvaging pumps to remove possible floods of oil or water. All this work was preparatory to attempts to extinguish the blaze. In the area immediately surrounding the flaming well twenty derricks were either burned down, pulled down, injured or had operations suspended due to the fire.

Following the preparatory work many different methods of extinguishing the fire were attempted. All of these methods had as the first requisite the saving of the well for future production. Any one of these methods which were

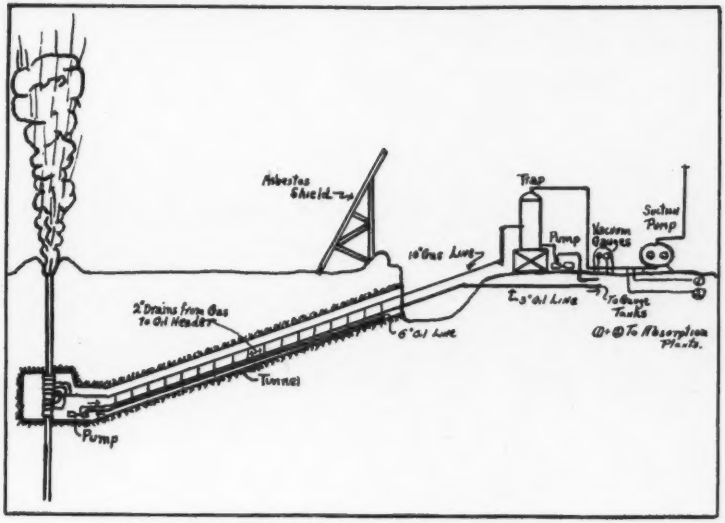
The Getty oil well fire after the attempt at surface control was abandoned. This picture shows the congestion of wells in this "town lot" field; twenty other derricks were destroyed or so exposed that drilling operations had to be suspended.

unsuccessful in this case, due to the peculiar conditions, might succeed in other cases.

The first attempt consisted of running thirteen four-inch steam and mud lines to fan in on one side of the well in an attempt to blow it out. This was abandoned, due to the danger of saturating the surrounding area with burning oil.

The attempt at underground control, which was finally successful, was then initiated. The plan was to tap the casing below the surface and shut off or relieve the pressure at that point, thus having only a comparatively small fire to extinguish at the casinghead.

A tunnel was started toward the well from a pit dug by a steam shovel about 250 feet from the burning well. This tunnel was timbered throughout in accordance with state regulations. Quicksand and loose sand above the water table, as well as cavities around the casing, greatly hampered this work. As the casing was approached, about 48 feet below the surface, tests were made in and around the drill pipe of the burning well for gas and oil before actually exposing the casing. The piping consisted of a 15½-inch outside casing and an 11-inch and a 9-inch inside casing with the 4-inch drill pipe in the center. Gas was flowing from the well through both the drill pipe and immediately outside the drill pipe inside the 9-inch casing. A chamber was excavated around the pipe. The outer casings were then tapped and various attempts made to reduce the gas flow by forcing into the space between the 9-inch casing and the drill pipe packing materials such as hard wooden balls, solid and hollow aluminum balls, lead and steel wool, asbestos, and various



Tunnel method of taking oil and gas from burning well.

other materials. At one time a wedge was made which resisted a 1,000-pound pressure only to be cut away by sand under gas pressure. At the same time a connection was made to the casing at the surface through which hematite, cement and barite were pumped into the well, but with little effect in reducing the flow.

An attempt from the tunnel was then made to control the flow in the drill pipe by inserting a large wooden ball, followed later by an aluminum ball. This was partially effective and afforded an opportunity to insert large quantities of mud at 600 pounds pressure, but even this was ineffective in controlling the fire.

It was then decided to attempt control of the fire by connecting the casing and drill pipe to a large gas line leading up to the surface through the tunnel. The amount of suction on this line from compressors on the surface was not sufficient to remove any considerable amount of gas and oil, so a difficult engineering problem was solved by means of drains from this gas line to a smaller oil line which was connected to oil pumps driven by compressed air and located in the tunnel chamber. In this manner approximately 2,500 barrels of oil and 8,000,000 cubic feet of gas were recovered daily while the well was still burning. The fire was reduced about 75%, making possible attempts to cap the casing at the surface. Extinguishing the remaining fire with steam and mud streams was first tried out but found ineffectual, although the fire was reduced to such an extent that it was possible to set a steel bell

Starting the tunnel to reach the casing of the burning Getty well about 50 ft. below the surface. The structure between the fire and the pit is an asbestos screen to cut off radiated heat.

with standpipe over the reduced flame. A 12-inch gas line was connected to the side of the bell to remove the gas below the flame to a remote point, then the valve on the standpipe was closed and the flame on top extinguished.

The Belleview Oil Well Fire.

The Belleview Oil Syndicate well was located in the same congested town lot drilling section as the Getty No. 17, only nearer the heart of the field, close to the famous "Four Corners." Early on November 9th this well became a burning inferno soon after it had started production from the deep sand. Partially due to knowledge gained in fighting the Getty fire, control of the Belleview fire was made in the comparatively brief period of twenty-one days.

A conference of the neighboring companies affected by the fire resulted in the advancing of a fund to the Belleview Company to fight the fire and the appointing of a committee of engineers from the Union, Standard and Texas Oil Companies to direct operations. Under their direction a surface and underground attack was immediately planned against the burning well. While crews of men worked clearing the surface other crews started driving a tunnel toward the casing. Through the tunnel it was proposed to divert a portion of the gas and oil into flow lines, as had been done so successfully with the Getty well, should the initial surface attack prove a failure. It was thought worth the attempt, however, to try to cap the well at the surface.

After several days of hard as well as hot work, the ground was sufficiently cleared to start operations. A 40-foot flue was suspended over the casing by means of guy wires. A crane, mounted on a tractor and walled with sheet iron and asbestos to protect from the heat the operators, who all wore asbestos suits, moved the flue into place. With the flue over the casing the flames were

Wide World.

Belleview Oil Well Fire, Santa Fe Springs, Cal. This photograph shows the tunneling operations to reach the well casing. The flame from the burning well is not conspicuous in this picture against the background of the sky, but was said to be visible at night from a distance of fifty miles.

drawn from the surface and lifted the height of the flue (40 feet) above the surface. Two "wind machines" from Hollywood created an artificial breeze sufficient to enable men to work in close enough to the casing to prepare the way for the control manifold. When this was done the flue was removed.

The next step was to slip the specially prepared manifold over the casing. This manifold was built with a 25-foot 10-inch pipe attached to carry the flames far enough above the ground to enable men to operate the control valves. It was moved into place the same way the flue had been, and clamped over the casing. Failure was threatened because the warping by the intense heat of the pipes made a satisfactory shut-off impossible. This was overcome by welding a considerable quantity of metal to the casing by working upwards from a pit which had been dug around the casing.

Twenty-one days after the fire started the big valve in the control manifold was ready to end the Belleview well's uncontrolled career. The "wind machines" were moved as close as possible. Firemen prepared to play streams of water on men who would have to work in close to the casing. A 30-foot remote control lever was attached to the main valve, but the pressure was too great for success from this distance, so several men in their asbestos suits, armed with large pipe wrenches, moved up to the casing and, assisted by the men with the long lever, began turning the valve. Little by little the flame was lessened and with a final gasp was extinguished, while at the same time the oil and gas that had been feeding the flaming torch was turned into a flow line leading to gas separators.

Since the surface attack had succeeded, the tapping of the drill pipe in the completed tunnel was not necessary.

Estimates as to the flow of oil during the fire were from three to seven thousand barrels and the gas from twenty to forty million cubic feet. Immediately after the fire the actual production was 2,800 barrels of oil and 30,000,000 cubic feet of gas per day.

Comparison of these two fires would show even to the most casual observer the individualistic character of oil well fires. The Getty fire gave off great volumes of dark smoke above the orange-colored gas flame, showing that large quantities of oil as well as considerable gas were burning. On the other hand, the Belleview fire resembled a huge welding torch with its orange flame, making a weird sight, especially at night. This fire was primarily a gasser, burning comparatively a small amount of oil. All of which leads to the conclusion that oil well fires to be properly controlled must be studied by competent engineers as individual problems.

Preble Box Toe Co. Explosion and Fire.

Lynn Mass., November 8, 1928.

Twenty persons lost their lives and a number were injured when an explosion occurred shortly after 7:30 o'clock on the morning of November 8, 1928, in the Preble Box Toe Company plant in Lynn, Massachusetts. The blast was followed by a huge burst of flame which extended high into the air and to all sides, enveloping near-by frame dwellings. The factory building was wrecked and the adjacent dwellings badly scorched.

Construction.

The plant consisted of a one-story solid concrete block, single area building, 125 ft. x 50 ft., with a small boiler room cut off by a metal-clad door. The roof was of reinforced concrete, 5 in. thick, supported on unprotected I-beams and cast iron columns. All windows were wired glass in metal frames with the center section a swinging sash.

The front of the building was set back from Brookline Street about twenty-five feet, and the rear was flush with Groveland Street. A two-story frame dwelling, occupied by the Blaney family, was located eleven feet away from the factory on the west, beyond which were numerous frame dwellings. Other frame dwellings and outbuildings were located thirty feet and more distant on the north and east side.

Occupancy.

The plant was occupied by the Preble Box Toe Company, whose principal business was the manufacture of pyroxylin impregnated cotton flannel from which box toes for cheaper grades of women's shoes are cut. They also mixed box toe softener, and made an adhesive, similar to rubber cement, for the use of shoe manufacturers. All processes involved the use of flammable solvents.

Processes.

The first step in the process of making box toe stock was to dissolve pyroxylin plastic scrap, popularly known at the plant as celluloid, in ethyl acetate and denatured alcohol. For this purpose pyroxylin novelty scrap was used. The process was carried on in seven mechanically agitated churns which had a capacity of approximately 280 gallons each. The second step consisted in impregnating the cotton flannel with the pyroxylin solution from the churns. The cotton flannel, from rolls one yard wide, was drawn over a steam radiator and then through an open tank containing approximately 150 gallons of the

This report has been prepared through the co-operation of two N.F.P.A. members, the Eastern Underwriters Association Inspection Bureau and the inspection department of the Associated Factory Mutual Fire Insurance Companies. Data obtained through the above sources have been supplemented by inspections made by engineers of the N.F.P.A. and information from other sources. While the available evidence is conflicting with respect to some points, this report is believed correct in all essential features.

Interior of the workroom of the Preble Box Toe Co. at Lynn, Mass., showing drums of flammable fluid piled at the left, the mixing tanks, the heating coil over which the cloth was passed, and the drying rack.

pyroxylin solution. A wooden knife removed any excess solution from the flannel as it came from the tank, after which the flannel was drawn up a short conveyor and festooned over steam coils on an open rack about 65 ft. long. The rack had a steel track and the flannel was hung on angle irons which were moved along the track by hand. After drying, the material was cut into sheets about 6 ft. x 4 ft. and packed in wooden cases for shipment.

The adhesive was made from purchased gum, which was mixed with benzol in four mechanically agitated mixers. This process was carried on in the part of the building directly adjacent to the Blaney dwelling.

The box toe softener is a mixture of di-acetone and denatured alcohol, and was sold to the trade in five and ten-gallon cans.

The raw materials used in these several processes were stored in one open area around the machinery and equipment used in manufacturing and along the west and rear walls of the building. As near as can be ascertained the approximate amount of stock on hand at the time of the fire was as follows: 600 lbs. of pyroxylin novelty scrap in wooden barrels and boxes, five 50-gallon drums of ethyl acetate, two drums of benzol, two churns of di-acetone, twelve drums of denatured alcohol, and possibly eight large boxes of finished box toe stock. In addition there were thirty-five large rolls of cotton flannel, most of which were in a separate stock room in the front of the building, and some fifty empty drums in various parts of the plant. The festoon dryer was full of coated cloth.

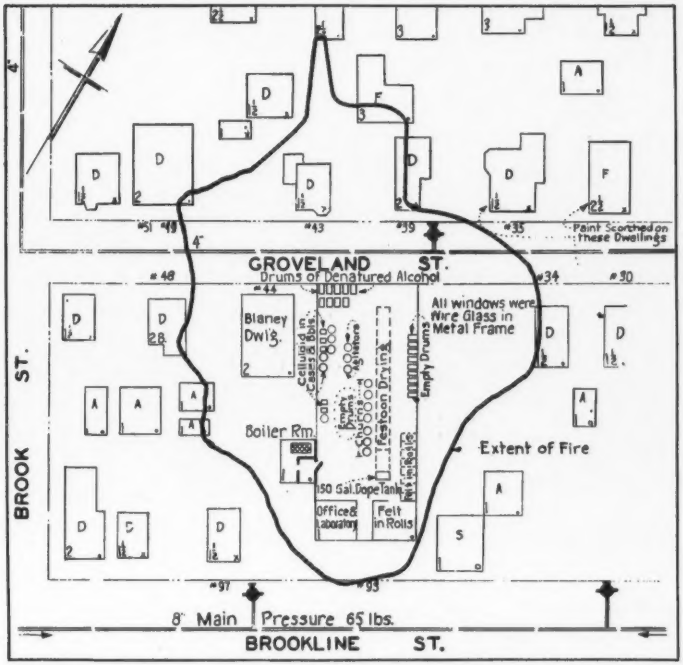


Diagram of the Lynn, Mass., explosion and fire of November 8, 1928, showing the extent of the fire resulting from the explosion of flammable gases and vapor in the Preble Box Toe plant. Approximate scale, 1 in.=85 ft.

Fire Protection.

Safeguards from fire were meager, the only inside protection consisting of several foam extinguishers. Apparently an attempt had been made to have the electrical equipment conform to the standard for hazardous occupancies. Lights were all said to have been enclosed in vapor proof globes. Most of the wiring was in conduit and some of the motor switches were located outside the main room in the partially cut off boiler room. There were, however, several snap switches in the main room, as well as a motor starting box. There were three small A.C. motors located on the ceiling and several small window fan motors, none of which were of the vapor proof type.

Story of the Fire.

In accordance with the regular practice, sheets of cloth, soaked with the pyroxylin solution, were festooned on the frames to dry from the heat from the steam coils. In the morning, when the factory was opened at 7:30, it was the custom to open the doors and windows and air the place out with the blower. The weather the morning of the fire was damp and misty, a fact which tended to keep the fumes confined within the building.

Concrete block end wall blown into street as a result of explosion of flammable vapor in the plant of the Preble Box Toe Co., Lynn, Mass.

At 7:34 A.M. a fire occurred in the northerly end of the building, closely followed by a terrific explosion which blew out the entire north wall and caused the collapse of a portion of the roof at that point. The flames shot across Groveland Street for a distance of 120 feet, acting much like a huge blowtorch, and ignited four frame dwellings. Other dwellings on either side of the factory were also ignited. Flames shot into the Blaney dwelling, next to the factory, with particular violence and this dwelling was immediately enveloped in flame. The first explosion was followed by subsequent explosions of lesser violence, due apparently to gases formed by the decomposition of the pyroxylin in the coated fabric, of which there was a large quantity near where the fire started, and possibly in vapors of solvents or from the drums of solvents.

Of the fifteen male employees who were in the plant, thirteen lost their lives. Four of them were blown out on Groveland Street, burned to death, three were crushed under the crumpled walls and fallen roof in the north end of the building, and three ran out onto Brookline Street, living torches of fire. Two others were burned to death just outside the plant on Brookline Street, and another was found just inside the doorway.

On the first floor of the Blaney dwelling there were a father, mother and seven children seated at breakfast when the blast of flame shot into the house. The mother and four children attempted to leave by the rear door, but were overcome and burned to death. They were found huddled together at the foot of a short flight of stairs leading to outdoors. The father and two boys escaped

Rear of the Preble factory, showing the proximity of the Blaney dwelling, where seven lives were taken by the burst of flame following the explosions.

by the front door into Groveland Street, but the father returned and rescued a sixteen-year-old daughter. Both were so seriously burned that they died later at a hospital. The two boys were slightly burned.

On the second floor of this dwelling was an elderly lady. She was slightly burned and received injury by broken bones from jumping from a window.

A fire alarm was promptly given from several fire alarm boxes in the vicinity, and a second alarm and general alarm quickly followed. The fire department quickly subdued the fire with a dozen water lines from their pumpers, and it was brought under control within thirty minutes. With the exception of the Blaney house the fires in the dwellings were not severe. The appearance of the dwellings, however, gives ample evidence of the intense heat to which they were subjected.

From the foregoing statements it is obvious that the hazards of the plant were severe, and there were many undesirable features and defects present, any one of which might have caused this fire or explosion. Among these were: storage of large quantities of pyroxylin scrap in barrels and wooden boxes, some of which were piled near steam pipes; storage of cotton flannel and drums of solvents against steam pipes; improperly installed electrical equipment; an opportunity for sparks, both mechanical and electrical which might have ignited the flammable vapors present; lack of safety cans or covered tanks for the handling of flammable liquids.

Looking across Groveland Street from the rear of the Preble factory at Lynn, Mass., showing the scorched and blistered paint on dwellings, evidence of the extreme heat.

From the evidence of injured persons, who were interviewed at the hospital before they died, it appears that an employee in some manner dropped a lighted cigar butt into a wooden rubbish barrel containing some pyroxylin scrap. Whether this happened as a careless gesture on the part of the employee in flicking the ashes of his cigar into the barrel, or whether, as was indicated by another witness, the employee put his cigar down on a stand and the force of air from the blower just started blew it into the barrel, will probably never be definitely determined. It seems apparent, however, that there was a fire just prior to the explosion, and an unsuccessful attempt was made by employees to extinguish the flames.

From this point on the progress of the fire was rapid. The heat and flame from the burning contents of the barrel apparently decomposed the pyroxylin scrap in boxes and barrels near by, thus forming explosive vapors, which, added to the flammable vapors already present in the building, exploded with terrific force, pushing out the rear wall, and was followed by a blast of flame.

The quick burning of the gases resulting in the intense blast of flame probably exhausted most of the oxygen in the building soon after the explosion, leaving little to support further combustion, so that there was relatively little fire inside the building. The dip tank, churns and most of the drums other than those in the northern end of the building did not ignite or explode, and woodwork and rolls of cloth were only slightly burned or charred.

The property loss to the plant is estimated at $30,000. Four dwellings were damaged to 50% or more of their value, and four others were slightly damaged.

Lessons of the Fire.

Failure to recognize and properly safeguard industrial hazards achieved in this instance its most tragic consequences. The great cost in human lives should give particular emphasis to the lessons.

In the first place adequate means should have been provided for the removal of flammable vapors. Drying operations should have been carried on in a separate enclosed room with adequate ventilation to outside air, with proper provision for the induction of fresh air. Ventilating fans were provided but were of insufficient capacity, and proper provisions for the ingress of fresh air were lacking.

Smoking or the carrying of matches into a plant of this character should have been strictly prohibited. From the evidence presented at the state fire marshal's inquest, it appears that it was a common practice for officials and employees to smoke in the office of the factory immediately adjoining the workroom.

Pyroxylin scrap should be stored in detached buildings having sufficient gas vent area and protected with automatic sprinklers. Volatile solvents should not have been stored in the same area with manufacturing processes, and the two hazardous manufacturing processes should have been carried on in separate rooms. As indicated above, the drying operations should have been kept separate from the mixing processes.

Flammable liquids should have been stored in outside underground tanks and handled by pumps, or in drums in a detached building, with only small amounts in safety cans brought into the main workrooms as needed.

The electrical equipment should have been properly safeguarded and installed strictly in accord with the National Electrical Code for hazardous occupancies. Although it was claimed that all lights were enclosed in vapor proof globes, there was at least one light not so enclosed at the Brookline Street end of the mixing room.

The employees should have been instructed to leave the building at once at the first sign of fire. Had this been done the loss of life might have been much less.

Sprinklers are valuable protection in this type of occupancy, even though in occasional instances explosions might break some of the piping before the heads open. It is important, of course, in this as in other occupancies, to catch a fire in its incipiency, and in this particular occupancy it may require a thermostatically controlled open head system.

The plant in question failed to comply in many respects with the N.F.P.A. regulations covering occupancies of this type.

Adequate regulations covering such hazardous processes, with the requirement of annual permit, and systematic and rigid inspections, will go far toward eliminating the probability of such disasters.

Hospital and Institution Fires.

Fire protection and fire prevention from a safety to life standpoint should have the strongest appeal in connection with the protection against fire and elimination of fire hazards in those classes of buildings occupied by the sick and the aged, who, because of their condition cannot quickly seek safety in event of fire; and children who are dependent upon their elders for providing safety and cannot provide it themselves.

That this appeal has been disregarded and that these serious responsibilities have been sometimes deplorably neglected by those in charge of the buildings and lives entrusted to their care is plainly indicated by the reports of the 184 fires in hospitals and institutions on file with the N.F.P.A. Department of Fire Record. The reports on which this record is based are those of fires since September 1, 1915, and while the number of fires reported to the N.F.P.A. is but a small fraction of the total number that have occurred during this period, the volume of data is sufficient to draw general conclusions as to the predominating causes of institution fires, the loss of life, the effectiveness of protection and like details.

The National Fire Protection Association has constantly emphasized the importance of institution fire safety and has consistently advocated fire-resistive hospital and institution buildings with proper exits, special fire protection for existing buildings, particular care in fire prevention and the various other measures applying. A code for the proper construction and exit arrangement of institution buildings has been developed by the Association through its Committee on Safety to Life, educational pamphlets on this subject have been published, and the QUARTERLY has regularly printed reports on important institution fires.

Safety to life in buildings of this occupancy requires: (a) Proper construction of buildings; (b) Adequate exits; (c) Careful housekeeping and protection of fire hazards; (d) A competent, trained staff having adequate personnel on duty at all times.

The modern trend in hospital and institution building construction represents a distinct improvement in construction over that prevailing a decade or more ago. Many of the more recently built institution buildings are of first-class fire-resistive construction with adequate fire protection. But there are still a large number of institutions being built in which fire safety has not received sufficient consideration; where the exterior walls are of substantial construction, giving the semblance of fire safety, but where the interior is "built to burn." Likewise in some cities much has been done to improve the

P. and A. Photo.

Ruins of Home for Incurables, Paremus, N. J., destroyed by fire December 14, 1925. One hundred and eighty helpless patients were hastily evacuated from the building.

safety of the older buildings. Some of the more dangerous structures have been abandoned altogether for institution purposes, others have been provided with automatic sprinklers, and other fire safety measures have been taken. But institutions continue to burn at the rate of one a day, according to the statistics of the National Board of Fire Underwriters.

Ample information is available in the publications of the National Fire Protection Association as to the proper construction and protection of institution buildings. Anyone who wishes to construct a fire-safe building or to remodel an existing building in the interest of fire safety can readily obtain information as to the best methods to follow. Unfortunately there still are many who have no conception of the seriousness of the fire problem and who must be shown detailed evidence before they can be persuaded to act to safeguard the sick, aged and dependent of their communities. This detailed evidence, the fire record, is familiar to all those who have made a particular study of this problem. The records of hospital and institution fires assembled on the following pages are not intended as the presentation of new data, but as a compilation of the fire experience in form available for convenient reference.

Safety to life from fire in hospital and institutional buildings requires that the superintendent and staff give attention to and take adequate measures to meet their responsibilities in all details affecting the fire safety of patients, which is often lost sight of where the needs for medical attention and care of patients absorb the attention of those in charge. Those in authority should be made to realize that the protection of the sick and helpless against loss of life

by fire or smoke is a responsibility of importance comparable to that of medical attention.

The material on the general subject of fires in institutions has been subdivided into a number of separate articles: famous institution fire disasters where major losses of life have occurred; a tabulation and statistical analysis of loss of life in institution fires; detailed records of other typical fires where loss of life has occurred; a comprehensive analysis of fires, including tables of causes, classes of buildings, places of origin of fire and the like, and selected reports of typical fires illustrating points of special interest, such as the hazard of X-ray film, the effectiveness of sprinklers, and the value of fire drills.

Famous Institution Fires.

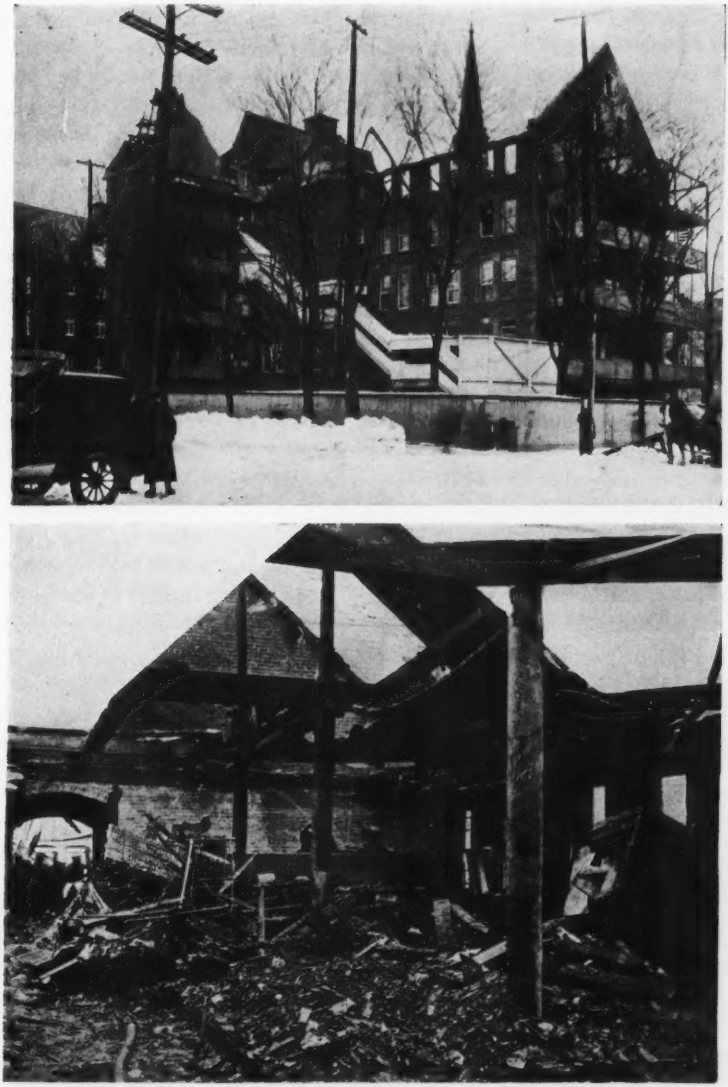
Five institution fires in which one hundred and seventy-two deaths occurred are described in detail in this article. There are included here the three major fire disasters of the past five years and the two previous institution holocausts to which reference is most frequently made. These fires have been selected for more complete treatment than can be given the other loss of life fires recorded in the following pages.

The Grey Nunnery, Montreal, P. Q., February 14, 1918.

A portion of the fifth floor of the west wing of the Grey Nunnery, in Montreal, was destroyed by a fire occurring in the early evening of February 14, 1918, resulting in the loss of life of fifty-three babies.

The home was a large stone building, occupying an entire city block, and part of it was occupied by convalescent soldiers. There were about one thousand persons in the building—two hundred returned soldiers, many nursing sisters, nuns, crippled people, aged and children. Although many of them were stretcher cases, all adults were taken out of the building without loss of life. Several of the returned wounded men, however, were seriously injured by falling débris before they could be reached by the large army of rescuers. A dozen or more had to be carried from the second and third stories on beds.

The fire started on the top floor, near the tower, and immediately ignited the curtains of a near-by window, from which it spread rapidly throughout the wooden interior. The returned soldiers who were not confined to their beds lent their efforts to the rescue work. When the first fireman arrived the soldiers were already at work, at great risk to themselves, in handing children down the fire-escapes. Nearly the whole upper floor was then ablaze. The firemen rushed in and seized children right and left. A sudden gust of flame and smoke which burst from the tower made it impossible to reach children still lying in their cots in that part of the building, but only upon the definite orders of the fire chief were the soldiers debarred from attempting further rescues.



West wing of Grey Nunnery, Montreal, after the fire of Feb. 14, 1918. In spite of unusual heroism on the part of nuns and convalescent soldiers, more than fifty children perished. Lower picture shows room from which firemen removed forty little bodies.

All of the top floor was occupied by babies in cots, some of them only a few days old. These were the infants lost, all the older children, who were in another part of the building, being saved. When the firemen had, after valiant work, got the fire under control, all the southern part of the top story had been destroyed and a great deal of damage done to the remaining part of the west wing. After the fire was extinguished thirty-eight little bodies were taken from the débris, and on the following day fifteen more were found.

Central Oklahoma State Hospital, April 13, 1918.

The Central Oklahoma State Hospital for Insane, at Norman, Oklahoma, was partially destroyed and thirty-eight inmates were cremated in a night fire which occurred on April 13, 1918.

The fire was discovered by the night watch in Ward 14 and by a negro inmate in Ward 15 (second floor) about 3:45 A.M., in or near a linen closet which was near the middle of the building on the first floor. Three wards and the general dining hall were totally destroyed with their contents; thirty-seven of the inmates of Ward 14 and one of Ward 15 (37 white and one negro) were cremated. The value of property burned was estimated at between $40,000 and $50,000.

The cause of the fire is unknown, some thinking it might have been caused from electric wiring, but there was nothing to substantiate the supposition except the absence of any other apparent cause to which it could be attributed. No electric lights were installed in the linen closet in which fire is supposed to have originated. A slight lightning storm was brewing at the time of fire, but no serious electrical disturbances were noted at or previous to the discovery of the fire. Upon discovery of the fire a general alarm was sounded by a steam whistle at the hospital power plant, and all ward watchmen, nurses and other employees proceeded to fight the flames with hand chemical extinguishers and one hose stream. Every effort was made to first get the inmates out of the burning and exposed buildings. It was claimed by the Norman public fire department that they were not called until about 4:15, or until after the fire had been in progress probably thirty minutes. During the fire a moderate wind was blowing from the southeast, and, but for the good work of the public department with the pumping engine, probably several other buildings would have been destroyed.

From information obtainable, it would appear that the fire was fought as satisfactorily as could be expected in view of the fact that removal of the inmates in the wards destroyed was a very slow and tedious procedure, due to their very inferior mental and physical condition. Due to the flimsy and rapidly combustible construction of buildings involved, the flames spread very rapidly, being fanned by a moderate southeast wind. It would appear that quite unnecessary delay was experienced in turning in the alarm to the public

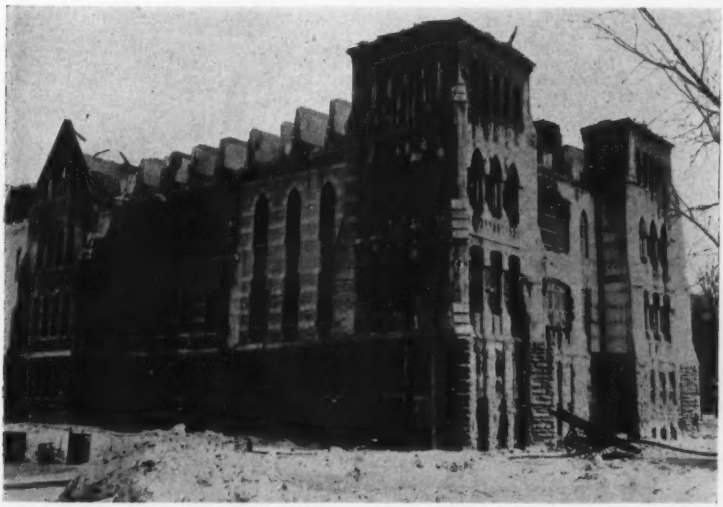
fire department, but no information was available as to the cause of this delay.

In the wards in which the fire originated and in which all the lives were lost, there was a total of 86 inmates—37 on the first floor and 49 on the second floor—one inside and one outside stair being available for exit from the second floor. All of the inmates of the lower floor were cremated and one from the second floor. The inmates of the lower floor being of the very lowest mentality, quite a large number of them were gotten out only to rush back immediately into the burning building. It is claimed that one night watch is stationed in each ward, but no approved clock service was employed and no record was obtainable on effectiveness of this service.

Manhattan State Hospital, New York, February 18, 1923.

The Manhattan State Hospital on Ward's Island contains over six thousand inmates and is one of the largest institutions for the insane in the world. The main structure, in which the fire occurred, was fifty years old and so built as to facilitate the rapid spread of fire. It had accommodation for 2,200 patients and there were about 1,600 in the building at the time.

In 1920 the National Board of Fire Underwriters made a survey of the institution and at that time recommended the installation of automatic sprinklers and other safeguards, pointing out that the buildings were lacking in fire-resistive features and contained blind attics and other concealed spaces which, together with the absence of protection for communicating passages and vertical openings (such as stairways and shafts), made the structures veritable



The ruins of the Manhattan State Hospital, a typical institutional building.

The fatal corridor on the third floor of the Manhattan State Hospital for the Insane on Ward's Island, New York Harbor, where twenty-seven persons met death on February 18, 1923.

fire traps. The engineer of the Board also stressed the inadequate and unreliable water supply and the poorly equipped fire-fighting force.

The superintendent of the institution recognized the fire hazard and had repeatedly tried to obtain more adequate apparatus and other assistance from state and city authorities. The island's fire department consisted of a fire chief and ten attendants who were detailed for fire service although they also had other duties. The equipment consisted of a motorized fire engine, an ancient horse-drawn engine, a hose cart and a hook and ladder truck.

The fire was discovered at 5:05 o'clock in the morning of February 18, 1923, by an attendant. An electric light went out and he noticed that the metal ceiling above was red hot. The attendants had the presence of mind to give the "all out for breakfast" call and succeeded in getting many of the inmates into the dining room out of danger before the flames burst through the ceiling. From then on the rescue work became more difficult, as the patients became excited and had to be dragged out by attendants.

The rescue work had been progressing rapidly when a large water tank in the attic fell through the ceiling and blocked the corridor. Firemen were unable to penetrate beyond the tank. There was a fire escape at the other end of the corridor, but the victims were apparently unable to reach it through the smoke and flames. Twenty-two patients and three attendants were burned to death. Two other patients died of exposure after being removed to another ward.

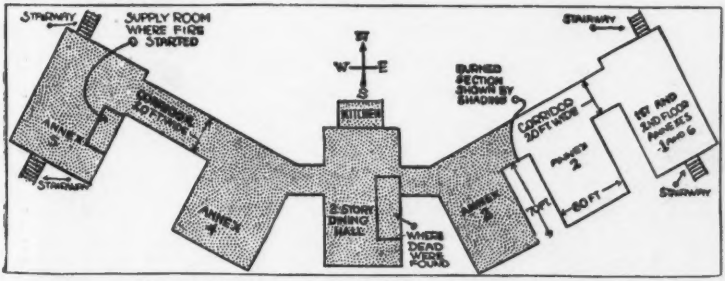
The fire fighting was hampered by the zero weather and the extreme difficulty in getting apparatus to the scene. The New York City force had to go to the fire without equipment, as there was only a small ferry, of insufficient capacity for fire apparatus, to the island. Fireboats had to run hose lines for nearly half a mile before water reached the fire. In spite of these handicaps the fire fighters, aided by fire walls, succeeded in confining the fire to the two upper floors of the west wing. The fire was not completely extinguished until noon, having raged for more than seven hours. The property loss was estimated at more than $200,000.

Illinois State Hospital for Insane, December 26, 1923.

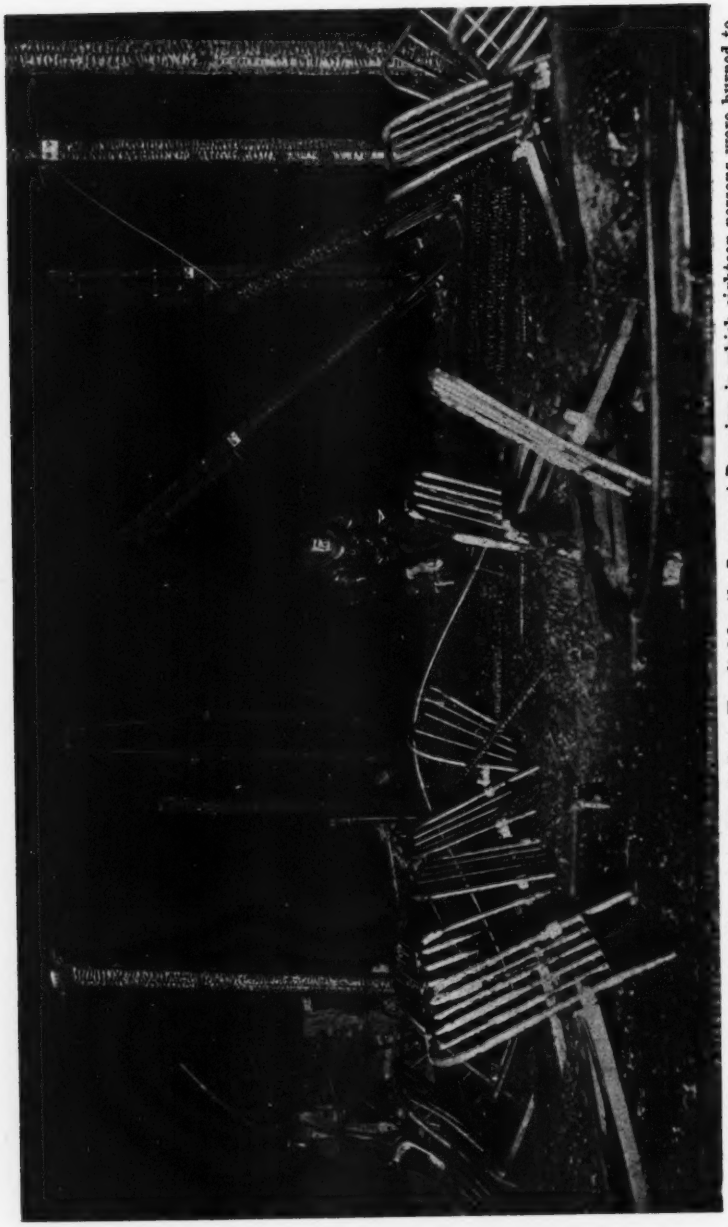
A fire which occurred during the evening of December 26, 1923, in a group of joisted frame buildings, part of the Illinois State Hospital for the Insane at Dunning (just outside of Chicago), caused the death of eighteen persons.

The past history of this institution is interesting. In 1912 the superintendent had called attention to the serious conditions then existing. On August 23, 1911, one of the buildings had been destroyed by fire. On January 17, 1912, another building burned to the ground. This building, built in 1870, had been condemned in 1908, but was forced back into use without remodeling because of overcrowded conditions. On May 4, 1914, another building was burned. On October 16, 1916, two barns on the grounds were destroyed by fire. On December 11, 1918, the tuberculosis ward, with 400 patients inside, took fire. The patients were rescued with great difficulty. After this fire the ward was rebuilt the same as before.

The scene of the fire was a group of six one and two-story frame buildings communicating through one-story frame passages 30 to 50 feet long. The central building was occupied as a dining room on the first floor and a dormitory above. The area was approximately 5,500 square feet. There was a two-foot unused space under the lower floor. Floors were double one inch



Plans of the buildings involved in the Dunning Insane Asylum fire.



Ruins of the frame annex building of the Illinois State Hospital for the Insane at Dunning, in which eighteen persons were burned to death on December 26, 1923.

boards on ordinary joists. The walls and ceilings were wood sheathed. The roof was prepared roofing on one-inch boards on ordinary joist and wood truss. Annexes 3, 4 and 5, which were destroyed, were one-story structures similar in construction to the dining hall portion and covering an aggregate area of approximately 10,000 square feet. The passageways were one-story frame with an approximate area of 6,200 square feet. The annexes were used for dormitories. Each dormitory was provided with wooden bins in which the patients' clothes were stored, and small enclosures in which mops, brooms and cleaning materials were kept.

The buildings contained about 300 patients, mostly epileptic, but some violently insane kept on the second floor over the dining room. Many of the patients had received Christmas cigars and cigarettes and they were allowed to smoke in the buildings without restriction. The mop closet in each dormitory contained polishing mops made of six-inch pipe wrapped with discarded bed linen and blankets. Paraffine wax was rubbed on these mops, which were used for polishing the floors. The buildings were heated by steam, the radiators being covered with wire mesh and sheet metal guards.

A private hose reel with 300 feet of hose was kept in a frame shed located within 150 feet of where the fire started. A city hydrant was approximately 300 yards distant. The nearest city engine company was 3½ miles away. No watch service was maintained. A few 2½-gallon soda-acid extinguishers were provided.

The fire was discovered at 5:40 P.M., when all the patients were at supper in the dining room, by a patient who habitually stayed behind to say prayers. It started in the mop closet in Annex No. 5. The cause has not been definitely established, but it is probable that spontaneous ignition of the mops or defective electric wiring was responsible. The patient immediately shouted "fire" and a nurse in the dining room telephoned to the operator in the Administration Building, who sent the alarm to the power house, where a siren was sounded. A city fire alarm box located in front of the Administration Building was pulled at 5:41 P.M. The fire spread rapidly and the patients in the dining room were hustled out of the building and lined up outside. There were only eighteen guards to handle the patients, some of whom were violently insane and all of whom were panic stricken. The doors of the dining hall opened inward, creating a jam, and the lights went out, adding to the confusion. A number of the patients eluded the guards and ran back into the building to save personal belongings. Most of these burned to death. A caretaker and his wife, who had rooms on the second floor over the dining room, went back to get their eight-year-old son. They remained to pack up some belongings and all three perished.

The guards marched the patients to the Administration Building. On the way the violently insane patients bolted and many escaped into the city.

Firemen digging for bodies in the ruins of the Illinois State Hospital for the Insane.

Three men broke out of the line and ran back into the building and locked themselves into a lavatory on the second floor. Policemen entered and broke down the door and were able to force the patients down ladders to safety.

The private fire brigade had a fairly good hose stream playing on the fire when the city department arrived, but the buildings were all aflame and some walls were already falling. The wind had been blowing from the southwest and sweeping flames directly toward the other wards, but fortunately at this time it shifted and the firemen were able to save annex buildings one and two. Seven engine companies and four truck companies responded to the fire. The roads had been transformed to deep mud on account of a heavy rain and great difficulty was experienced in moving the apparatus. Fourteen bodies were found in an area of approximately 300 square feet at the rear of the dining room.

Hospice St. Charles, Quebec, P. Q., Dec. 14, 1927.

The Hospice St. Charles in the City of Quebec was visited by fire on the evening of December 14, 1927, with the loss of thirty-seven lives. The victims were children, the majority of them being little girls between five and nine years old.

The Hospice St. Charles was an orphan asylum consisting of a main building built in 1831 and an annex consisting of two adjoining parts built in 1920 and 1925. At the time of the fire there were three hundred and seventy-one children asleep in the various dormitories and about twenty sisters in charge. While this institution is designated as an orphanage, it served also as

The Hospice St. Charles, a Quebec orphanage, burned on the night of December 14, 1927. Thirty-seven children were burned to death in this building, despite heroic attempts at rescue. The building, like many others of its class, had substantial exterior walls, but a highly combustible interior. Fire started in the basement and spread rapidly through rubbish chutes and up open stairways.

a school, and the three hundred and seventy-one children included many with living parents whose frantic efforts to find their children added to the confusion and intensified the horror of the catastrophe.

The exterior walls of the building were of stone. The interior was of wooden joisted construction. The central portion was four and one-half stories high and the two wings were three and one-half stories high. With open stairways and open refuse chutes leading from the various floors to the basement, the interior construction of this building favored the rapid spread of fire. There were three wide stairways, and two iron fire escapes were provided on the rear of the building.

Between 8 and 9 P.M. one of the sisters made an inspection of the building and found everything in order, with no indication of smoke or fire. The exact time and point of origin of the fire are not definitely known, but it is clearly established that the fire started in the basement and there is a strong probability that it originated in a room which was used for storage purposes.

According to custom all children and the sisters had retired at 9 P.M. About 10:45 one of the sisters was awakened by the crackling sound of burning wood and she immediately rushed to give the alarm, which consisted of ringing the assembly bell. Others were apparently awakened by the smoke about the same time, and the testimony indicates confused shouting and cries of fire throughout the building.

The sisters marshaled their charges in the several dormitories and started them out of the building. Had it not been for the good discipline which appar-

ently prevailed it is probable that the loss of life would have been much larger. The smoke filled the building rapidly and the corridors and stairways were soon impassable. A large number of those rescued were taken down ladders by the fire department; some jumped or were thrown from the windows and were caught in life nets. It is not clear how many escaped by the different exits, but there is definite testimony that one of the fire escapes was used effectively during the early stages of the fire.

Apparently the greater part of the loss of life occurred in the section of the building directly over the point of origin of the fire. One of the sisters testified that many of the children from five to nine years old who lost their lives had returned to certain death in the dormitories after having been started toward the exits. There is a report that as one group of children marched from their dormitory they were met by a cloud of smoke from which they recoiled and retreated to their beds, shortly to be suffocated there.

The heroine of this fire, Rose Anna Gaudreault, was a young girl of seventeen who lost her life in an attempt to rescue the youngest of the children of whom she had charge. When last seen she was mounting the stairs to go to the children on the third floor. Nearly two hours later her body was found in a corridor on the third floor, near the entrance to a room where several little girls were found dead on their cots.

The first alarm for this fire was transmitted from a box located in front of the main building. This box was "pulled" by a passer-by at 10:48 P.M. A second alarm was turned in by a policeman at another box at 10:55 P.M., and a general alarm was turned in by a deputy chief of the fire department at 10:56 P.M. On arrival of the first section of the brigade, heavy smoke was found issuing from the basement windows, also flames from the roof on the southwest side of the building. Lines of hose were immediately laid from hydrants about 250 feet distant and carried through the yard at the rear of the building to the basement. Water is stated to have been turned on without delay, but the use of the streams was abandoned at the outset, firemen turning their entire attention to the work of rescuing the many children reported to be confined in the building and who at first were understood to have been safely removed.

Men responding to the second alarm also united with those already engaged in rescue work. Nine or ten ladders were unshipped from trucks by this detachment and thrown over the high iron fencing surrounding the building grounds. This unusual procedure was due to the fact that trees and heavy accumulations of snow prevented trucks from being readily driven into the grounds, and was the cause of considerable delay in erecting ladders against the building. Two aerial trucks, for use on the central or higher portion of the building, subsequently entered the grounds through the main gateway but were only suitably placed after some trees had been cut down.

About the time the general alarm was transmitted two lines of hose were laid directly from a hydrant located in the grounds opposite the main entrance of the building. These lines were carried up ladders and water directed through windows on the upper floor. Attention was next directed to laying additional lines directly from near-by hydrants and the placing of pumping engines. With engine and direct hydrant streams in service, the fire was fought from the street level, roof of the kitchen at rear, taking lines of hose into the second story of the building and up ladders raised for the purpose. During the course of the fire the temperature was moderate and there was little or no wind.

Indications are that most of the victims who lost their lives were killed by suffocation rather than by burns, although after the fire it was found that many of the bodies were so badly burned as to make identification difficult. Most of the children died in the building, but two of those rescued alive died later in a hospital. The coroner's jury in its investigation of the disaster returned a verdict of accidental death, but added to its verdict a demand "that more effective supervision be required during the night, and that automatic sprinklers be installed in all buildings of this kind."

Loss of Life in Institution Fires.

In compiling the fire record of institutions printed on page 319 there were found to be thirty-three fires in which loss of life occurred. These fires include the well-known institution holocausts as well as numerous fires in which only a few people were killed. It is by no means a complete list, but includes enough fires to permit generalization as to the factors causing these losses of life. A number of fires are included in which employees, nurses and firemen, rather than patients or inmates, were the victims. The list of fires classified by occupancy, using the classification chosen in discussing the general fire record of institutions in this issue, follows:

Almshouses.

Allegheny County Almshouse, Angelica, N. Y., March 15, 1923. Two men and seven women lost their lives in a fire caused by a gas explosion.

Poorhouse, Pepperell, Mass., March 30, 1926. Woman crippled by rheumatism was suffocated in her bed.

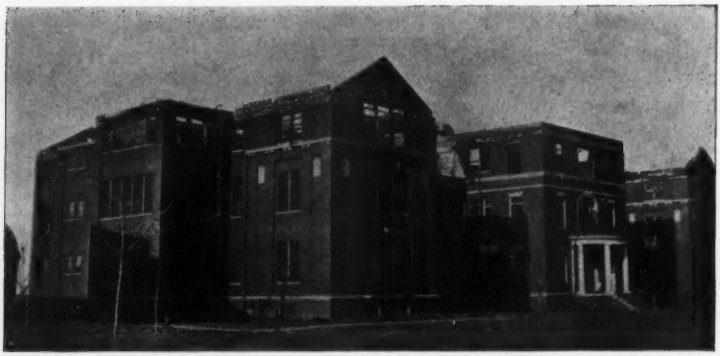
Homes for Aged.

Masonic Home, Wichita, Kans., Dec. 22, 1916. Boiler improperly installed fell from supports, causing fire in which five elderly persons lost their lives, together with a young girl who returned to building for her belongings.

Lynn Home for Aged Women, Lynn, Mass., Feb. 23, 1920. Janitor dropped match in rubbish which had accumulated in basement. Four elderly women were suffocated before they could be rescued.

Miscellaneous Homes.

Salvation Army Industrial Home, Cincinnati, O., Dec. 16, 1913. Five men killed in fire of incendiary origin.



Wayne County Insane Asylum, Elloise, Michigan, after the fire of March 27, 1923. Substantial walls gave the semblance of fire safety. Two hundred patients were marched to safety; two lives lost.

Orphanages.

St. Francis Girls' Directory, San Francisco, Cal., Sept. 4, 1915. Five girls lost their lives. There were no fire escapes.

Jewish Orphans' Home, Shawbridge, P. Q., Aug. 16, 1922. Midnight fire cost the lives of the caretaker, his wife and two children and eight orphans.

Buckner Orphans' Home, Dallas, Tex., Jan. 2, 1923. Fire of unknown origin at night cost the lives of two children. No fire protection was available.

Catholic Mission, Lewiston, Ida., Oct. 4, 1925. Oil lamps used to save electricity. One "exploded" and started fire which cost lives of six boys.

Northern Pier Orphanage, Harrison Valley, Pa., Jan. 7, 1927. Explosion of heating equipment cost life of one child. Child was ill with measles and overcome by smoke. She died in hospital the following day

Baptistine Sisters of Nazarene, Peapack, N. J., Nov. 8, 1927. Three children trapped in building lost their lives.

Hospice St. Charles, Quebec, P. Q., Dec. 14, 1927. Thirty-eight children were burned or suffocated in an incendiary fire which destroyed a large portion of the building.

Hospitals.

Harney County Hospital, Burns, Ore., Oct. 29, 1915. One patient burned to death in fire caused by match thrown into wood-box.

Grey Nunnery, Montreal, Que., Feb. 14, 1918. Sixty-three babies lost their lives in fire which destroyed upper floors of building.

Telfair Hospital, Savannah, Ga., March 8, 1920. Vapor lamp overheated and set fire to baby's crib. Child died.

Deer Island Prison Hospital, Boston, Mass., May 20, 1921. Two trusties lost lives by being overcome by smoke. One was on the roof and fell in the building, the other was in the building.

Vista Grande Health Resort, San Jose, Cal., March 7, 1922. A patient, partially incapacitated, attempted to get out of bed, overturning oil heater. She lost her life and another was severely injured.

Essex County Tuberculosis Hospital, Middleton, Mass., March 29, 1922. Current was left on electric flat iron all night in nurses' room, causing fire which destroyed top floor of dormitory and cost life of one nurse.

Hospital for Incurables, Montreal, Can., March 15, 1923. One patient died from the effects of the fire.

Hospice Gamelin, Montreal, P. Q., Jan. 4, 1924. Fire was caused by defective elevator motor. One patient died from shock after removal from building.

Scobey Hospital, Boston, Mass., Jan. 4, 1925. Fire started from short circuit of wiring on Christmas tree. One patient lost her life when all means of escape were cut off.

Isolation Hospital, Bridgeport, Conn., March 26, 1926. Patient removed from building died from exposure and shock.

Penobscot General Hospital, Oldtown, Me., April 6, 1926. Employee overcome in attempt to escape from room on third floor.

Ramsey County Preventorium, Lake Owasso, Minn., April 10, 1927. Fireman trapped in burning building was so severely burned that he died soon after being rescued.

Memorial Hospital, Albany, N. Y., March 17, 1928. Eight deaths occurred following a fire in which fumes from burning films were liberated in hospital building. At least three or four deaths were probably due to the inhalation of fumes, while one was known to be due to exposure and heart attack.

Insane Asylums.

Connecticut Hospital for Insane, Middletown, Conn., Jan. 10, 1918. Five patients lost their lives in early morning fire which originated from unknown cause in attic.

Central Oklahoma State Hospital, Norman, Okla., April 13, 1918. Three wards and dining hall destroyed. Thirty-seven white patients and one negro patient lost their lives. Many of them had been gotten out only to rush back again into the building.

Ohio State Hospital, Gallipolis, Ohio, March 10, 1920. Patient confessed to setting fire which caused nine patients to be suffocated.

Walter Reed Hospital (Psycopathic Ward), Washington, D. C., Dec. 12, 1920. Fire was caused by careless smoking by insane patient, who was burned to death.

Manhattan State Hospital, Ward's Island, N. Y., Feb. 18, 1923. Fire supposed to have been caused by spontaneous ignition of accumulated dust and rubbish in hot air ducts caused the death of twenty-two patients and three attendants.

Wayne County Asylum, Elloise, Mich., March 27, 1923. Tinner's blow-torch started fire which destroyed building and cost lives of two patients who rushed back into rooms. The 200 other patients escaped safely.

Dunning Insane Hospital, Chicago, Ill., Dec. 26, 1923. Fire broke out at suppertime, trapping patients in dining room. Fifteen patients, an attendant, his wife, and small child were burned to death.

Hartford Retreat, Hartford, Conn., July 3, 1926. One patient locked in room was suffocated to death. Two other patients and two firemen were overcome by smoke, but recovered.

The tables which follow summarize the causes of the loss of life rather than the cause of the fire. The tables follow the general plan used in the Loss of Life Fire Record (*Quarterly*, Vol. 18, No. 3, page 296) and the Fire Record of Loss of Life in Dwellings (*Quarterly*, Vol. 20, No. 4, page 385), and Loss of Life in School Fires (*Quarterly*, Vol. 21, No. 2, page 144). Thus a fatality due to a fire originating in rubbish in a basement would, depending on the circumstances, be classed as "suffocation while asleep" or "inadequate exits" rather than as due to rubbish. Where direct fire causes are cited as causes of fatalities, this means that the loss of life was due to burns or ignition of clothing by the originating cause of the fire. The tables are thus prepared on an entirely different basis from the usual fire record tables.

The loss of life per fire is high, 8.3 persons. This is swelled by the several holocausts included in this record, and by the fact that the record is not complete. This figure is somewhat lower than the figure of 14.1 per fire for schools, but much higher than the figure of 2 per fire in dwellings or the figure of 6 per fire in other occupancies, as shown by the previously compiled loss of life fire records.

Loss of Life in Institution Fires.

Number of fires in which lives were lost		33
	Number	Per Cent
Men killed	81	33.3
Women killed	32	13.2
Children killed	130	53.5
	243	100.0
No data as to sex or age	30	
Total number of lives lost		273
Loss of life per fire included in this record		8.3
Number of injuries recorded in these fires		16

The number of injuries recorded includes only those stated in the reports. In many cases no statement of injuries was made, and the actual number of injured is obviously much greater than 16.

The following tables are for the most part self-explanatory. In almshouses, homes for aged and miscellaneous institutions there have been few serious disasters. This is perhaps due to the fact that in these institutions the occupants are not entirely helpless and dependent on others for rescue in case of fire. It is in the hospitals, orphanages and insane asylums, both public and private, that the great disasters have occurred. As in school fires the majority of these have been due to the lack of adequate or properly arranged exits. In cases where there was more than one exit available the arrangement was often such that the fire cut off both exits.

In a number of fires the loss of life resulted from the fire starting at night while the occupants were asleep. Ill-advised attempts at salvage and re-entering the building on the part of insane or mentally weak inmates were the cause of numerous losses of life.

Loss of Life in Institution Fires by Occupancy.

	Total Fires	Total Lives Lost	Lives Lost. Men	Women	Children	No Data	Injuries (Where stated)
Almshouses	2	10	2	8	0	0	1
Homes for Aged	2	9	2	7	0	0	1
Miscellaneous	1	5	5	0	0	0	0
Orphanages	7	67	1	1	65	0	0
Hospitals	13	83	5	13	64	1	13
Insane Asylums	8	99	66	3	1	29	1
Total	33	273	81	32	130	30	16

Causes of Loss of Life in Institution Fires.

Fatalities classified according to the immediate cause of the loss of life rather than according to the cause of the fire.

	Number of Deaths.						
	Alms-Houses	Homes for Aged	Misc. Homes	Orphan-ages	Hos-pitals	Insane Asylums	Total
Construction.							
Fatalities which would have been prevented by superior construction. Cases where loss of life is due to failure to escape from a burning building, whatever the primary cause of fire, are classified under construction.							
Inadequate exits	—	4	—	47	64	—	115
Inadequate exits—barred windows	—	—	—	—	—	41	41
Attempt to descend using stairway	—	—	—	—	2	—	2
Fire extending from basement, cut off exits	—	4	—	—	—	—	4
Jumped to death from window	1	—	—	—	—	—	1
Burned to death while asleep	6	—	—	—	—	—	6
Night fire, people asleep, no data as to just how deaths were caused	—	—	—	4	—	5	9
Suffocated while asleep	1	—	5	8	—	9	23
Total							201
Burns and Ignition of Clothing.							
Classified in accordance with the direct cause of death, including cases where the victim died of burns, irrespective of whether or not the building was ignited.							
Burned by gas explosion	1	—	—	—	—	—	1
Oil heater upset	—	—	—	—	1	—	1
Total							2
Fire Fighting, Salvage, and Returning to Burning Building.							
Fatalities resulting from remaining in buildings to fight fires which were beyond control, or from entering burning buildings in ill-advised attempts to save valuables.							
Re-entering burning building	1	1	—	7	—	43	52
Fire fighting—trapped in building	—	—	—	—	3	—	3
Total							55
Special Hazards.							
Vapor lamp set fire to crib	—	—	—	—	1	—	1
Fumes from burning film	—	—	—	—	7	—	7
Total							8
Miscellaneous.							
Patient too ill to be moved	—	—	—	1	—	—	1
Died from exposure or due to weakened condition	—	—	—	—	5	—	5
No data	—	—	—	—	—	1	1
Total							7
Grand Total	10	9	5	67	83	99	273

Other Loss of Life in Institution Fires.

Almshouses.

ALLEGHENY COUNTY ALMSHOUSE, ANGELICA, N. Y., MARCH 15, 1923. Seven women and two men perished when a two-story wooden structure, housing twenty-four women inmates burned about midnight. The fire started from a gas explosion in the basement and so quickly spread that the dormitory together with the administration building was a mass of flames.

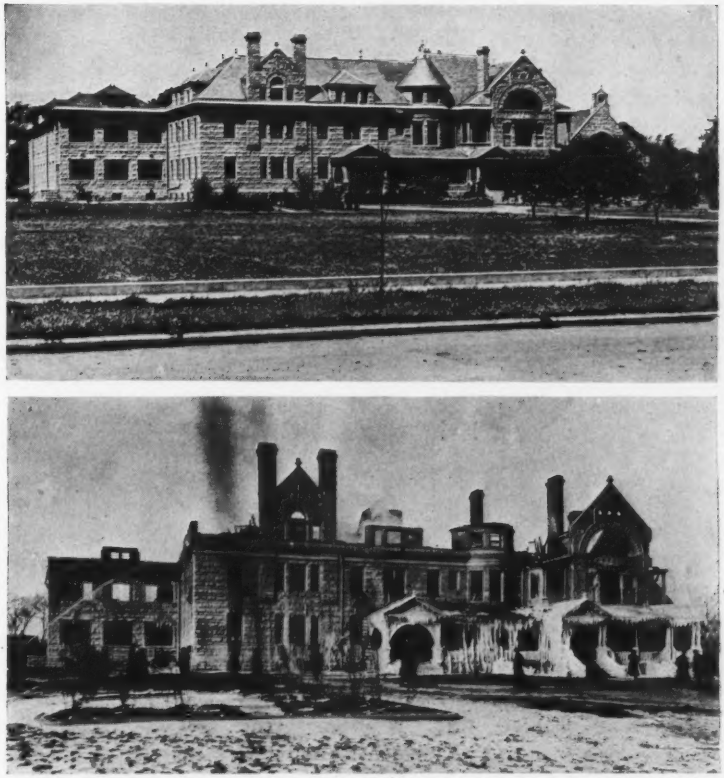
The night fireman was killed by the explosion. Six of the women were burned to death in their beds and the seventh was killed when she leaped from an upper window of the building. The other man who lost his life, an employee, was credited with unusual bravery. Three times he made his way into the burning building, each time bringing out a woman. On his fourth trip back into the structure the floors caved in and he burned to death.

The almshouse was an old wooden structure forty-five years old. The right wing burned in 1918 and was replaced by a concrete addition. This resisted the fire, but the rest of the structure was wholly consumed. The building was located three miles from the village of Angelica and volunteer firemen from the village did not reach the scene until the fire had nearly burned itself out. (H-19135.)

Homes for Aged.

THE MASONIC HOME, WICHITA, KANSAS, DECEMBER 22, 1916. Fire occurred at 1:55 A.M., completely destroyed the building with a loss of approximately $200,000, and caused the loss of five lives. The building was occupied as a home for old and needy Masons and their orphaned children.

The building was of stone, two and three stories in height, built in three sections not divided by fire walls. It had wooden floors with metal and shingle roofing. The building was heated by two steam boilers located in the basement near the center of the building. One of the boilers was very poorly supported and it seems clear that it fell and broke the pipes which fed fuel oil to the boilers from outside tanks. The fire was first discovered by inmates, who were awakened by the noise and by smoke in the rooms. A boy, aged 16, who was supposed to be in charge of the boilers, had fallen asleep and in his excitement on being awakened by the fire, he accidentally cut out all the lights in the building instead of shutting off the oil pumps. The oil spread over the floor of the basement and the institution was doomed. The firemen responded promptly to a telephonic call for aid, and, although they were prevented by the extreme heat from gaining entrance to the basement or first floor, they did heroic work in rescuing the inmates, of whom there were more than a hundred. Five lives were lost despite their efforts,—two old men, two old women, and one young girl who returned to the building to get her clothing. (H-12228.)



The Masonic Home in Wichita, Kansas, before and after the fire of December 22, 1917. This imposing structure, which looked safe to a layman, was destroyed with a loss of five lives, because of a wooden interior and no adequate fire protection.

HOME FOR AGED WOMEN, LYNN, MASS., FEBRUARY 23, 1920. Fire starting soon after 6:00 A.M. completely wrecked this structure which was a large frame dwelling, approximately 100 years old, converted to (not built for) this occupancy. The origin of the fire was attributed to the janitor dropping a lighted match in combustible rubbish, with which the floor of a basement storeroom is said to have been "littered."

Four of the aged inmates were suffocated and many others were rescued with much difficulty by firemen. (H-16541.)

Orphanages.

SHAWBRIDGE, QUEBEC, AUGUST 16, 1922. A fire occurring at midnight completely destroyed the Hebrew Orphans' Home and caused the death of

twelve persons, ten of whom were under 14 years of age. The orphanage was a three-story frame structure without any fire escape or means of protection against fire. There was no fire fighting apparatus in the village. The fire, starting from unknown cause, rapidly consumed the building. Twenty-nine boys sleeping on a balcony on the first floor were easily rescued. The caretaker, his wife and two children, and eight children in an adjoining room on the second floor were trapped and burned to death. (H-19073.)

LEWISTON, IDAHO, OCTOBER 4, 1925. Fire, caused by the "explosion" of an oil lamp, in the little Catholic Mission in the Nez Perce Indian Reservation took the lives of six orphans.

The fire started at 10:30 P.M. in the dormitory where thirty-one boys lay asleep. The nuns worked heroically to awaken the boys, dragging them from their beds. The sisters believed they had escorted all of the boys from the building when five of them dashed back to rescue some companion who, they thought, was facing death.

The bodies of the six were found closely huddled together in the ruins. The victims were from 5 to 14 years old. (H-22561.)

PEAPACK, N. J., NOVEMBER 8, 1927. Three children lost their lives when the dormitories of an orphanage were destroyed by fire while they were asleep. All of the children in one of the dormitories were rescued by a sister, with the exception of one who wandered off in the smoke toward the fire and was probably killed when a section of the floor gave way. In an adjoining dormitory two other children lost their lives when they wandered away in the smoke. (H-25093.)

Hospitals.

ESSEX COUNTY TUBERCULOSIS HOSPITAL, MIDDLETON, MASS., MARCH 29, 1922. This fire occurred in a hospital building of frame construction occupied as a nurses' home. The fire was discovered by a nurse on the third floor. She became excited and confused and fell unconscious. She died from extreme heat and breathing heavy smoke.

The fire originated in a nurse's room which had not been occupied since early on the previous evening. The nurse had asked permission to take an electric iron to her room and notwithstanding orders to the contrary, the matron had allowed her to do so. She attached it to a baseboard socket and when she left, apparently concluded that by turning off the main switch which controlled the lights she also disconnected the iron.

Fortunately there was no further loss of life as the fire did not break out until morning. The building was badly damaged. (H-18417.)

SCOBEY HOSPITAL, BOSTON, MASS., JANUARY 4, 1925. A fire, starting on Sunday afternoon, when a flash from a supposed short-circuit ignited the lower branches of a dismantled Christmas tree, swept the hospital clean, trapping 18 patients, two of them infants, and snuffing out the life of one woman

Fire Engineering.

The Scobey Hospital, Boston, a private hospital, burned on January 4, 1925. Down these ladders civilians and firemen carried the helpless patients, who were mostly "surgical cases." Those who were able to move crowded out on to the small balconies and endured the smoke pouring from the windows behind them until rescuers reached them.

before firemen and their ladders could reach the crowded windows to carry to safety the invalids, their nurses and some visitors trapped there.

All of the 16 adult patients were "surgical cases" and all were confined to their beds. That more of them and their attendants and their visitors were not burned to death when fire cut off—in less than two minutes—all means of escape except the windows, was due to desperate rescue work by nurses, doctors, civilians and firemen.

There were four women engaged in taking down the Christmas tree in the front room of the first floor when the fire started. They tried to smother it with rugs, but the highly combustible tree, window curtains and wooden trim burned with amazing speed and swept up an unenclosed wooden stairway and into the adjoining building because the third floor fire door had been fastened open. The single fatality was due to the spread of fire through this opening.

The building had been made over for hospital purposes by taking two four-story residences and cutting two doorways through the fire wall that separated them. One opening was at the first floor and the other at the third. These openings had fire doors which were not automatic, and which were fas-

Fire Engineering.

Scobey Hospital, Boston. Fire starting in Christmas tree decorations spread with astonishing rapidity up this unprotected stairway, making it impassable, and on through a fire door which was fastened open, snuffing out the life of a patient in the adjoining section of the building.

tened open at the time of the fire. The lower one was closed after the fire began, but the upper one, remaining open, permitted the fire to spread to the next building, causing the one loss of life and trapping the patients who were above the third floor.

The construction was ordinary brick with joisted frame interior and wooden unprotected stairways and a great deal of wooden trim, especially on the first floor. In accordance with municipal regulations the basements were

sprinklered, but this protection did not extend to the rest of the building. (H-21585.)

CHILDREN'S PREVENTORIUM, LAKE OWASSO, MINN., APRIL 10, 1927. The building, a large frame structure, was used as a dormitory and had a dining hall attached. Fire, which started from an unknown cause, was first seen coming through the roof. Firemen entered the building and were trying to save some of the contents. While thus engaged one of their number was trapped in a room by the falling of part of the floor and ceiling of the attic. This blocked the door and knocked him down, igniting his clothing. Although stunned, he jumped to the ground where the fire in his clothing was extinguished, but he died from his burns a few hours later. (H-24548.)

Fire Record of Hospitals and Institutions.

The files of the Department of Fire Record of the National Fire Protection Association contain reports on one hundred and eighty-four institution fires, including buildings of all classes used for institution purposes except jails and prisons. These latter were not included because a large proportion of the fires listed occurred in shops and workrooms, representing the hazards of industrial occupancies. Most of the fires recorded here occurred in the past ten years—only four of the fires having dates prior to 1917.

The record is by no means complete and does not include many of the small fires which are occurring daily in institution properties. The reports from insurance inspection organizations, which are the principal source of data on fires in industrial properties, are found in comparatively small number in the institution fire record classification. This may be because of the absence of insurance on many public or semi-public institutions or because the money losses involved are not of sufficient interest to the insurance organizations to justify the expense of investigation and the preparation of detailed reports. Many of the reports are based on newspaper accounts which have been verified by local N.F.P.A. members. Insurance inspection bureau reports are, however, the source of data on a majority of the private hospital and institution fires.

In view of the character of the original data, which include the larger and more important fires but not a fair proportion of the smaller fires, this record may not be completely representative. The record, however, includes a sufficiently broad selection of the important institution fires of the past decade so that there can be no question as to the validity of conclusions drawn in the tables here.

The extent of institution fires is shown by figures compiled by the National Board of Fire Underwriters, which indicate that fires occur in institutions at the rate of more than one a day and that the annual loss in institutions in the United States alone is over $1,000,000, if the usual allowance be made for unreported fires.

Fire Engineering.

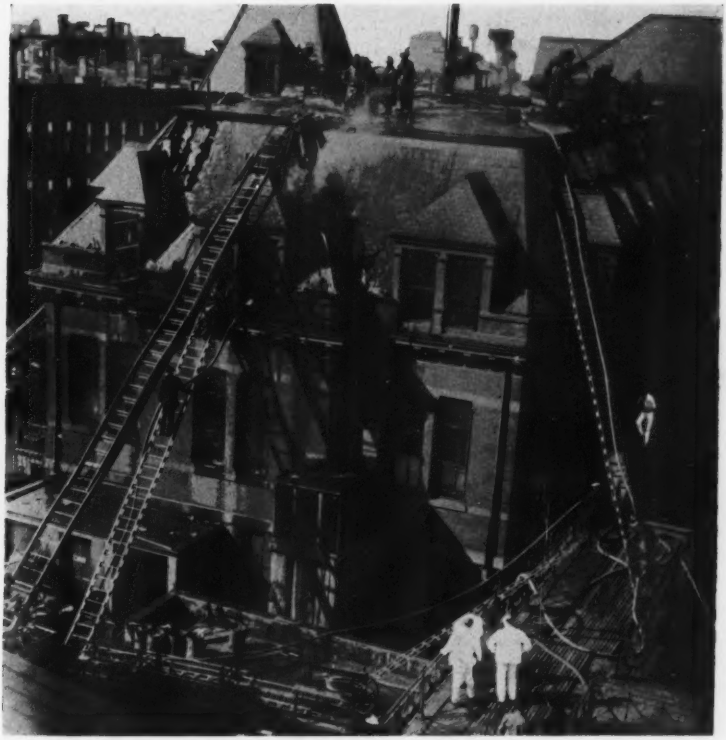
A typical shingle roof fire in the Midwood Sanitarium, Brooklyn, N. Y., a private maternity hospital. The fire shown, June 12, 1928, was the third roof fire experienced by this hospital.

The relative frequency of institution fires can be determined by the following table, which shows the number of fires occurring in institutions in widely separated communities over a period of ten years.

Year	City of New York	City of San Francisco	State of Massachusetts	City of Baltimore
1918	17	9	—	4
1919	30	11	9	10
1920	36	13	11	8
1921	32	12	9	7
1922	40	8	7	9
1923	37	20	—	6
1924	37	10	14	3
1925	36	4	13	6
1926	35	15	15	8
1927	42	16	20	10
	342	118	98	71

It was interesting to note in compiling these figures that the greater number of fires were in hospitals.

Practically every kind of institution is included in this record. The table on the next page shows the number of fires recorded in each type of institution:



Fire Engineering.

Methodist Hospital, Brooklyn, N. Y., fire of October 31, 1927. Seventy-eight patients were carried to safety. One life was lost.

Kind of Institution.	No. Fires
Almshouses	10
Homes for Aged	17
Misc. Homes	3
Orphanages	28
Hospitals	104
Insane Asylums	22
Total	184

The next tables show the causes of institution fires, one prepared from N.F.P.A. records, and the other supplied by National Board of Fire Underwriters. A third table gives similar figures for the State of Massachusetts. These data, from separate sources, agree as closely as can be expected for sets of figures compiled on a different basis: two including a relatively small num-

Causes of Fires and Places of Origin in Institutions, from N.F.P.A. Fire Record.

Cause	*Occupancy*							*Origin of Fire*											
	Total	Almshouses	Homes—Aged	Misc. Homes	Orphanages	Hospitals	Insane Asylums	Outbuildings	Roofs	Kitchen	Heat and Power	Other Service Departments	Patients' Quarters	Film and X-Ray	Other Operating Depts.	Nurses' Quarters	Attics	Misc.	Not Known
Electrical causes	39	2	4	0	3	23	7	1	0	0	1	8	9	4	0	5	5	3	3
Sparks on roofs	19	1	2	0	3	12	1	0	19	0	0	0	0	0	0	0	0	0	0
Incendiary	13	3	1	1	1	4	3	2	0	0	0	3	5	0	1	0	2	0	0
Stoves, furnaces, boilers and their pipes	11	0	3	1	3	4	0	0	0	2	6	0	1	0	0	0	1	1	0
Careless smoking	7	0	1	0	0	5	1	0	0	0	0	2	3	1	1	0	0	0	0
Defective chimneys and flues	7	1	0	0	3	3	0	0	1	1	0	1	0	0	0	0	2	0	2
Ignition of grease or flammable liquid on stove	7	0	0	0	0	6	1	0	0	4	0	1	0	0	2	0	0	0	0
Spontaneous ignition	7	0	0	0	1	4	2	0	0	0	1	6	0	0	0	0	0	0	0
Misc. known causes	7	0	1	0	2	5	0	0	0	0	2	2	0	2	0	0	0	1	0
Defective oil burner	3	0	0	0	1	2	0	0	0	0	2	0	1	0	0	0	0	0	0
Lightning	3	0	0	0	0	3	0	0	0	0	0	3	0	0	0	0	0	0	0
Careless use of matches	2	0	1	0	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0
Escaping gas ignited	2	1	0	0	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0
Lamp or stove upset	2	0	0	1	0	1	0	0	0	0	0	0	2	0	0	0	0	0	0
Steam pipes	2	0	0	0	0	2	0	0	0	0	0	0	0	1	0	1	0	0	0
Careless fumigation	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0
Explosion of lamp or stove	1	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Gas jet igniting curtain	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0
Gasoline ignited	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0
Unknown	49	2	5	0	10	25	7	0	0	5	0	17	8	2	1	1	7	0	8
	184	10	17	3	28	114	22	3	20	14	12	46	31	10	5	8	17	5	13

ber of fires classified in accordance with number of fires due to each cause, and the other on the basis of money loss and susceptible of distortion by reason of one or two large loss fires due to a relatively infrequent cause.

Fire Losses in Hospitals, Sanatoriums, Asylums, and Homes for the Aged, Years 1922 to 1926 inclusive.

National Board of Fire Underwriters.

Cause	1922 Property Loss	1923 Property Loss	1924 Property Loss	1925 Property Loss	1926 Property Loss	Total
Sparks on roofs	$78,912	$115,397	$67,961	$88,680	$100,259	$451,209
Stoves, furnaces, boilers and their pipes	89,245	63,891	43,094	17,077	55,442	268,749
Matches—smoking	28,984	49,191	31,929	58,010	59,714	227,828
Chimneys, flues, cupolas and stacks, overheated or defective	45,815	40,624	26,474	41,381	55,973	210,267
Exposure	59,540	57,087	32,400	10,678	31,890	191,595
Spontaneous combustion	71,109	26,893	14,710	49,911	27,875	190,498
Electricity (except electric irons and similar small devices)	9,739	51,605	35,085	28,535	27,693	152,657
Petroleum and its products	26,175	51,820	10,615	23,662	20,642	132,914
Lightning—buildings rodded and not rodded	9,384	33,937	11,182	40,063	14,989	109,555
Gas—natural and artificial	18,643	38,606	4,882	6,523	442	69,096
Hot irons (including electrical devices)	30,599	1,235	5,516	2,996	2,491	42,837
Hot ashes and coals—open fires	1,616	1,379	14,540	14,635	5,254	37,424
Friction, sparks occasioned by running machinery	9,010	178	6,744	852	12,013	28,797
Incendiarism	2,129	817	3,410	21,091	837	28,284
Open lights	4,353	2,396	15,036	3,745	1,232	26,762
Explosions	10,873	3,396	120	155	108	14,652
Hot grease, oil, tar, wax, asphalt, ignition of	1,445	1,651	1,603	2,187	1,297	8,183
Sparks arising from combustion	401	1,063	231	3,165	2,430	7,290
Steam and hot water pipes	.....	3,791	167	.....	937	4,895
Rubbish and litter	1,888	297	1,093	220	.....	3,498
Fireworks, fire crackers, balloons, etc.	204	3	25	179	.....	411
Miscellaneous—cause known but not classified	15,342	3,862	23,659	21,489	8,177	72,529
Unknown	288,570	443,027	309,896	407,252	338,608	1,787,353
Total	$803,976	$992,146	$660,372	$842,486	$768,303	$4,067,283
Average loss per year						$813,456

Causes of Fires in Institutions, State of Massachusetts—1918-1927 Inclusive.

	No. Fires		No. Fires
Careless smoking	20	Lamp or stove upset	1
Sparks from chimney	12	Malicious mischief	1
Overheated cooking or heating equipment	11	Lightning	1
Careless use of matches	9	Friction	1
Electrical causes	7	Gas or electric iron	1
Heating or Lighting equipment igniting merchandise	5	Defective heating apparatus	1
Defective chimney	4	Hot ashes	1
Spontaneous ignition	4	Fireworks	1
Children and matches	2	Volatile flammable liquids	1
Sparks from furnaces, stoves, fireplaces, etc.	2	Miscellaneous known causes	1
Explosion of lamp, lantern or stove	2	Unknown	6
		Not stated (1921-22-23 causes not classified)	33
			127

The foregoing tables of fire causes indicate that institutions are not particularly different from other occupancies, as the more common fire hazards head the list. Eight items are responsible for 106 out of 135 fires listed in the N.F.P.A. fire record, or 78% of the fires for which the cause is reasonably well known.

Electrical causes lead the list of fire causes with thirty-nine fires attributed to this cause. "Defective wiring" as a fire cause is always open to question, and it is possible that in a number of fires in this record in which this cause was assigned there may be some doubt as to whether or not it was the actual cause. An analysis of fires attributed to electrical causes shows them to be classified as follows:

	No. Fires
Defective wiring	22
Electric iron left on	5
Short circuit—X-ray machine	3
Short circuit on Christmas tree lights	2
Short circuit ignited gas in elevator well	1
Short circuit in lighting fixture	1
Electric light bulb ignited holiday decorations	1
Defective elevator motor	1
Electric light bulb ignited X-ray film	1
Radio charger left on	1
Arc due to fuse gap bridged with pennies	1

The number of fires on wooden roofs from chimney sparks confirms the already existing evidence that wood shingles are unsuited to use as a roof covering. Many of these fires were in institutions located beyond city limits or in small towns where a lack of fire protection allowed the complete destruction of the building. City institutions and institutions of considerable size are ordinarily provided with fire retardant roofings. Roof fires occurred from the causes listed on the next page.

All that remained of the Hebrew Orphans' Home, Shawbridge, Quebec, after the fire of August 16, 1922. Twelve lives were lost in this three-story frame structure.

	No. Fires
Sparks from chimney	9
Sparks on roof from previous fire	2
Flue burned out and set fire to roof	2
Janitor left slide on waste paper chute open and burning paper ignited roof	2
Sparks in wood cornice	2
Sparks or heat from roofer's soldering furnace	1
Workman using acetylene torch on roof	1

Next on the list are incendiary fires. A number of these, the reports definitely show, were started by insane or mentally weak inmates. Others appear to have been the work of pyromaniacs not inmates of the institutions involved in the fire.

Stoves, furnaces, boilers and their pipes, together with defective oil burners and defective chimneys and flues, were the cause of 21 fires. An analysis of this group is interesting, as follows:

	No. Fires
Defective chimneys and flues	7
Leaky oil burner on hot water heater	1
Leaky oil piping	1
Faulty installation	1
Overheated furnace	5
Overheated chimney	1
Excess heat under range	1
Heat from boiler ignited floor	1
Heat from gas stove ignited floor	1
Explosion in heater	2

Careless smoking and careless use of matches appear as a relatively minor hazard, but it is probable that a portion of the fires classed as unknown could be accounted for by this cause. Fires from this cause occur both in the service sections and patients' quarters, indicating a fair distribution of the hazard between employees and patients.

	No. Fires
Careless smoking—no specific data	2
Careless use of matches—no specific data	2
Match tossed in clothes chute	1
Cigarette dropped into film drawer	1
Cigarette ignited curtain	1
Cigarette dropped into oily rags	1
Cigarette tossed back of radiator	1

Ignition of grease or flammable liquids on stoves is a preventable cause, and an indication of poor housekeeping and carelessness. The specific causes clearly show this:

	No. Fires
Grease on stove	2
Kettle of syrup in drug room boiled over	1
Floor wax on stove boiled over	1
Rubbing alcohol ignited while being heated	1
Medicinal oil ignited while being heated	1

Miscellaneous known causes account for seven fires. The following analysis of this classification shows these fires to have been largely preventable:

	No. Fires
Rubbish near heater	1
Explosion of disinfecting fluid	1
Film ignited in motion picture booth	1
Rubbish ignited	1
Support for boiler gave way, breaking oil pipes	1
Ignition of film in storage	2

The following table indicates the manner of discovery of fire.

Manner of Discovery of Fire.

Number of Fires in Each Kind of Building.

Fire discovered by	Almshouse	Homes for Aged	Misc. Homes	Orphanages	Hospitals	Insane Asylums	Total
Employee	3	5	1	14	66	16	100
Patient or inmate	2	4	2	3	8	4	21
Outsider	3	1	—	5	12	1	20
Sprinkler alarm	—	—	—	—	7	—	7
Not stated	2	7	—	6	11	1	26
	10	17	3	28	104	22	184

The discovery of fires by employees has been further analyzed and it has been found that of the 100 fires so scheduled six were discovered by watchmen, 27 by nurses, and 77 by other employees. Further details are lacking, so that

definite conclusions cannot be accurately drawn, but it seems obvious that employees, as a whole, have not been lacking in their vigilance against fire.

A brief summary of the time of day of fire indicates that they were about equally divided between day and night.

Time of Day of Fire.

Institution	Total Fires	6 A.M. to 6 P.M.	6 P.M. to 6 A.M.	Not Known
Almshouses	10	5	5	0
Homes for Aged	17	10	4	3
Misc. Homes	3	1	2	0
Orphanages	28	14	12	2
Hospitals	104	45	49	10
Insane asylums	22	10	12	0
Total	184	85	84	15

The time of year of occurrence was divided as follows: 62% of the fires reported occurred in the period from November 1 to May 1, and 38% during the warmer months.

Construction of Buildings.

Number of Fires.

	Almshouse	Homes for Aged	Misc. Homes	Orphanages	Hospitals	Insane Asylums	Total
Brick or stone walls with wooden interior	2	10	1	11	50	14	88
Frame	8	5	1	10	41	5	70
Fire-resistive	—	—	—	—	3	1	4
Not stated	—	2	1	7	10	2	22
	10	17	3	28	104	22	184

The predominating construction of the institutional buildings involved in the fires recorded is, as the above table shows, "ordinary construction." That is, masonry walls with wooden interior. About half of the buildings in this classification were described as of brick and wood-joist construction—the remainder were described variously as "brick" or "stone," the usual meaning of these terms being that the walls were of brick or stone but that the interior was of ordinary wooden construction. It is possible that some of these were in reality brick-veneered only. It is somewhat less likely, though of course possible, that there may be a few fire-resistive buildings included in this classification. Usually a fire in a fire-resistive building is a sufficient surprise to warrant mention of the type of construction in the report. It may be assumed therefore that the majority of these fires were in buildings of combustible construction.

Very few of the institutions included in this record were fire-resistive. A few were partly so: some had fire-resistive walls, corridors, etc., but otherwise constructed of wood; some had fire-resistive basements only, and a few were fire-resistive except for the roof.

Wide World.

Soldiers' Home, Sawtelle, California, fire of July 12, 1927. This is a typical example of an institution building of frame construction and without adequate fire protection.

The relatively higher number of frame structures included is due to numerous fires in small or private institutions located beyond city fire limits, where restrictions as to construction are very meager or altogether lacking.

The combustible construction was responsible for the complete destruction of many of the buildings in these fires. The combustible wooden interiors, basements not cut off, stairways unenclosed, all contributed to the spread of fire. These fires were difficult to control even where the fire department arrived promptly.

The following analysis of the losses reported shows how large a proportion of the fires in this record were severe losses. This is due partly to the fact that the N.F.P.A. Department of Fire Record does not receive reports on the many inconsequential fires. The generally combustible construction, usual delay in discovery of the fire, and frequent lack of fire protection are reasons why the loss is ordinarily large when an institution building catches fire.

Analysis of Losses by Classes of Institution.

	Total		Number of Fires								
	No. Fires	Total Known Loss	No. Fires Slight Loss	Loss Under $1000	Loss $1000 to $10,000	Loss $10,000 to $50,000	Loss $50,000 to $100,000	Loss Over $100,000	Large Loss, Not Definite	Loss Not Stated	No. Fires Involving Total Destruction
Almshouses	10	$291,743	0	0	2	7	1	0	0	0	7
Homes for Aged...	17	659,380	3	0	5	5	1	2	1	0	2
Orphanages	28	961,015	3	0	6	6	3	2	2	6	5
Hospitals	104	3,267,747	19	10	17	29	10	4	4	11	24
Insane Asylums....	22	1,653,349	1	1	7	5	1	7	0	0	5
Misc. Homes.....	3	80,750	0	0	1	2	0	0	0	0	0
Total.....	184	$6,913,984	26	11	38	54	16	15	7	17	43

Only a very few of the buildings in which these fires occurred were equipped with automatic sprinklers. The performance of sprinklers was uniformly good, however, controlling the fire in all instances.

The small number of sprinklered fires is primarily due to the fact that a relatively small proportion of institutions have been equipped with automatic sprinklers. Also, where sprinklers are installed, such fires as occur are often controlled with the opening of one or two sprinklers and a negligible loss, and so are not reported. Partial sprinkler installations protecting basements, laboratories, kitchens and other hazardous portions are frequently found in institution properties; this accounts for the relatively large number of fires where the sprinklers were not a factor.

Effect of Sprinklers.

	Homes for Aged	Hospitals	Insane Asylums	Total
Extinguished fire.....	—	11	—	11
Held fire in check.....	—	3	1	4
Failed to extinguish fire.....	—	—	—	—
Not a factor*.....	2	6	—	8
Total.....	2	20	1	23

*By "Not a factor" is meant fires in sprinklered buildings where the fire was extinguished before it was large enough to open the sprinklers, or where the fire occurred in an unsprinklered portion of the building.

Summary of Sprinkler Efficiency.

	No. Fires	%
Practically or entirely extinguished fire	11	73.5
Held fire in check	4	26.5
Total where performance was satisfactory	15	100.0
Unsatisfactory	—	—
Total	15	100.0

Part of Institution Where Fire Originated.

Number of Fires.

Location	Total	Almshouses	Homes for Aged	Misc. Homes	Orphanages	Hospitals	Insane Asylums
Outside of Building							
Roof	20	1	2	—	3	13	1
Outbuildings	3	3	—	—	—	—	—
Service Bldg. or Room							
Kitchens	14	1	1	—	3	8	1
Storerooms	10	—	1	—	1	8	—
Basements	16	—	4	1	7	3	1
Closets	3	—	1	—	1	—	1
Laundry	9	—	1	—	—	6	2
Laundry chute	4	—	—	—	1	3	—
Power and heater room	8	—	1	—	—	7	—
Air shaft	1	—	—	—	—	1	—
Elevator shaft	3	—	—	—	—	3	—
Switchboard	1	—	—	—	—	1	—
Transformer vault	1	—	—	—	—	1	—
Workshop	2	—	—	1	—	—	1
Service Room	1	—	—	—	—	—	1
Patients' Quarters							
Smoking room	1	—	1	—	—	—	—
Patients' rooms	3	—	—	1	—	2	—
Ward or dormitory	16	—	—	—	2	6	8
Misc.—bathroom, etc.	11	—	1	—	4	5	1
Operating Quarters							
Laboratory	2	—	—	—	—	2	—
Film storage—X-ray room	10	—	—	—	—	10	—
Operating room	1	—	—	—	—	1	—
Sterilizing room	1	—	—	—	—	1	—
Nurses or Employees Quarters	8	—	—	—	—	8	—
Miscellaneous							
Attic or roof spaces	17	3	1	—	3	7	3
Moving picture booth	1	—	—	—	—	1	—
Partitions	1	—	—	—	—	1	—
Office or reception room	3	—	—	—	—	2	1
Not stated or known	13	2	3	—	3	4	1
Total	184	10	17	3	28	104	22

General Location of Origin of Fire.

	Almshouse	Homes for Aged	Misc. Homes	Orphanages	Hospitals	Insane Asylums	Total
Outside of building	4	2	—	3	13	2	24
Service rooms	1	9	2	13	41	7	73
Patients' or inmates' quarters	—	2	1	6	13	8	30
Operating departments	—	—	—	—	14	—	14
Nurses or employees quarters	—	—	—	—	8	—	8
Miscellaneous known portions	3	1	—	3	11	4	22
Unknown	2	3	—	3	4	1	13
	10	17	3	28	104	22	184

The second table shows more clearly than the first the hazardous portions of the buildings. The service sections, including basements, kitchens and storerooms, stand out as the most frequent source of the fires. These have been known to be the most hazardous portion of such buildings. Member H. W. Forster, in his article on Fire Protection for Hospitals, Asylums and Similar Institutions (*Quarterly*, Vol. 13, No. 4, page 315) in discussing sprinkler protection, points out that even partial installations of automatic sprinklers, particularly for basements and other hazardous locations, would in many cases be helpful when funds are not available to sprinkler the whole building.

Roof fires are second in importance. This is due to the use of wooden shingle roofings, which is quite common on rural institutions and small frame buildings of private hospitals and asylums.

It would be interesting in the case of institution fires to know just how much a factor a fire drill might have been in getting people out of the building, or how frequently lack of it was a direct cause of fatalities. The reports in this record, however, do not show these facts except in a few cases. The following brief summaries do show, as far as data could be taken from the reports, how the exit was made in some cases.

Institution Fires Showing the Value of Drills.

BAIE ST. PAUL, CHARLEVOIX, P. Q., MAY 11, 1923. Fire which destroyed the north wing of the St. Ann Hospital for the Insane, involving a loss of $150,000, was discovered by one of the inmates at 2 o'clock in the morning. Drilled like soldiers and offering no trouble, the 250 male patients were marched downstairs to the first floor and rigged out in clothing which would keep them from suffering from the effects of the cool night. Immediately afterwards they were conducted to the outside and then into other sections of the hospital unaffected by the fire. Although the patients were all mental defectives ranging in age from three years to seventy-five, not a single casualty occurred and the sisters attributed this as much to the fine behavior of the majority of the patients as to their own heroic efforts. In the absence of fire

escapes, the utmost care had to be exercised to see that everyone was out of the building by ordinary passageways, and in this work of rousing the sleepers some of the volunteer fire fighters endangered their lives. (H-19566.)

MONTREAL, P. Q., DECEMBER 27, 1924. Sparks from a blaze not fully extinguished two hours previous were blown up the laundry chute of the Deaf and Dumb Institute and started a fire on the roof which menaced the institution. Sixty pupils of the institution carried out the fire drill taught them and marched in safety to another part of the building. There was no panic. The children formed in groups, as they had been carefully taught to do in time of danger, and marched to the ground floor of the building. The fire was not sufficiently serious to make it necessary for them to go outside. (H-21574.)

OTTAWA, ONT., DECEMBER 22, 1925. A fire believed to have been caused by the explosion of disinfecting fluids stored in a locker broke out in the Protestant Orphans' Home. Fifty-three children between the ages of three and eleven marched out of the blazing building in perfect order without a single child being injured. Splendid discipline was displayed by the youngsters throughout the excitement. (H-23144.)

BINGHAMTON, N. Y., JANUARY 27, 1927. Fire started in the attic of the Susquehanna Valley Home for Boys early in the evening. Fourteen boys occupied a dormitory on the third floor directly under where the fire broke out, and about 31 occupied a dormitory on the second floor. Some of the younger lads were preparing for bed when the fire was discovered, while others were on the main floor. At least once a week a fire drill is held at the institution, and so well drilled were the boys that they were able to get out to safety without a moment's delay and without the slightest injury to any one of them. The boys were sent down the spiral fire escape chute to the ground and from there were taken to other buildings. Repeated fire drills in which the spiral chute had been used plainly revealed the results of those drills. Not a youngster became excited as they dropped one after the other into the chute from the second and third floors to be helped to their feet as they reached the bottom of the chute. (H-22786.)

WORCESTER, MASS., DECEMBER 28, 1927. A short circuit in a wire of the electrical decorations on a Christmas tree was responsible for a blaze which drove out 900 of the 2,200 patients of the Worcester State Insane Hospital. The efficiency of the fire drill managed by the doctors and attendants was considered remarkable. Two minutes after the alarm had sounded and while the excitement was intense the 900 patients were marched to points of safety. The calmness and reassurance of the doctors and attendants worked such a magic on the patients in the east wing that the patients in other wings of the building were not even aware of the fire. (H-25380.)

Fires in Institutions with Automatic Sprinkler Protection.

ROME, N. Y., SEPTEMBER 15, 1917. Fire occurred about 3 A.M. in a private room of the Rome Infirmary on the fourth floor of the building. The fire was caused by a lace curtain being blown against an open gas jet. The fire was confined to the room of origin and was entirely extinguished by one of two sprinklers located in the room. The loss from fire was very small, but the water went through all floors to the basement and did considerable damage, due to the fact that there was no one in the building with any knowledge of the sprinkler system and valves, and some little time was lost before the water could be shut off. (S-22210.)

WEST HAVEN, CONN., DECEMBER 20, 1918. Floor wax was being heated in an open pan of water on a gas range and boiled over. The gas flame ignited the wax. One sprinkler head almost directly over the range opened and although a chemical extinguisher was brought into play the sprinkler extinguished the fire. The paint on the walls and ceiling was slightly damaged. (S-24454.)

NORTH DARTMOUTH, MASS., JUNE 4, 1920. Fire occurred at 4 A.M. in the laundry of a private hospital, due apparently to a short circuit on an electrically heated mangle. It was the custom of the head nurse to visit the room after it closed down for the day, but the night "watchman" (who was a woman) did not visit this room, as it would require her to go into the yard in the dark and around to the side of the building, where the only entrance is located. The smoke from the fire and the noise of the one sprinkler operating awoke a nurse sleeping on the second floor over the laundry and she turned in the alarm. The fire was confined to the mangle—the cloth covered roller being burned. The sprinkler entirely extinguished the fire. (S-29115.)

BINGHAMTON, N. Y., FEBRUARY 4, 1927. A graduate nurse set a one-quart bottle of rubbing alcohol inside a small agate basin and placed the basin over the lighted burner of a small gas stove in order to warm the alcohol. The stove was located in a small diet kitchen in the basement. She left the room and shortly after the alarm gong attached to the dry valve sounded. One sprinkler in the room was found operating and the fire entirely out. The glass bottle was shattered and no alcohol was found in the basin. There was practically no loss. (S-44634.)

BANGOR, MAINE, DECEMBER 23, 1926. A nurse was using an electric iron in a room over the kitchen for her personal clothing after hours and carelessly left the current on. The ironing board and cloth ignited, but the sprinkler operated and completely extinguished the fire.

WORCESTER, MASS., FEBRUARY 23, 1927. Fire started in the basement of the administration building in the room containing the X-ray machine generator. The apparatus was enclosed in a wooden case near the wall. Wires

leading to the machine ran along the floor back of the machine and it is supposed that fire was caused by short circuit in these wires. There were four sprinklers in the room, one of which opened and practically extinguished the fire. (S-44272.)

X-Ray Film Fires in Institutions.

Nitrocellulose X-ray film in hospitals or where the sick and infirm are cared for constitutes a very serious hazard, as the following fires indicate. Where film is mentioned in these fires the nitrocellulose variety is refererd to. Safety film, of cellulose acetate stock, is now available and photographically is the equal of the nitrate film. The acetate film has no greater hazard than a similar quantity of ordinary paper.

However, the nitrocellulose film does exist and constitutes a severe hazard unless properly stored. Compliance with the Regulations on this subject prepared by the N.F.P.A. Committee on Hazardous Chemicals and Explosives will do much towards eliminating this particular danger to the sick and helpless.

BOSTON, MASS., APRIL 25, 1923. This fire occurred in the X-ray film storage room in the basement of a hospital. The cause of the fire is said to have been an ordinary electric light bulb which accidentally came in contact with some of the film. Fortunately the basement was provided with automatic sprinkler protection. One sprinkler head opened and promptly extinguished the fire, which otherwise would have endangered the many patients on the floor above. This fire emphasized the hazard incidental to film storage and the value of automatic sprinklers. (S-35299.)

SYRACUSE, N. Y., SEPTEMBER 17, 1923. Fire occurred in a hospital, starting in the film storage closet in the X-ray room. The X-ray department was located on the first floor, occupying two rooms, with closets and an old bathroom space separating the rooms, and a similar room across the hall used for film developing.

The exposed completed negatives, some 12,000, were stored on 12-inch wooden shelves in the closet and on similar shelves in an adjoining recess without a door, and on three open racks in the operating room itself.

Fire was discovered by a nurse, who notified the doctor in the adjoining room. He immediately came in, opened the closet door, saw the fire burning along the edge of the lowest shelf, obtained a 2½-gallon soda-acid extinguisher and played it on the flames, but without effect, as in about one minute an explosion occurred which threw him about 15 ft. across the room and set fire to the nurse's clothing and hair.

This was extinguished by the doctor, who then immediately shut the door to the operating room and turned in a fire alarm. The firemen controlled the fire itself within a short time. Prior to this, however, a second explosion occurred, blowing out the windows in the rooms above the X-ray department

and bulging the partition to the storage closet in the X-ray department about a foot and a half. This was caused by the gas going in through the ventilators and blind space and down into the hollow partitions and up through to the second floor, and igniting when it obtained the proper mixture.

No definite cause can be ascribed, but it was probably due to decomposition on account of heat. There was no wiring of any kind in the closet. Two asbestos covered steam pipes passed through it, but there was no sign of charring at the floor passage, and the pipes were not within one foot of any negatives. The closet, however, was quite hot from the steam pipes passing through.

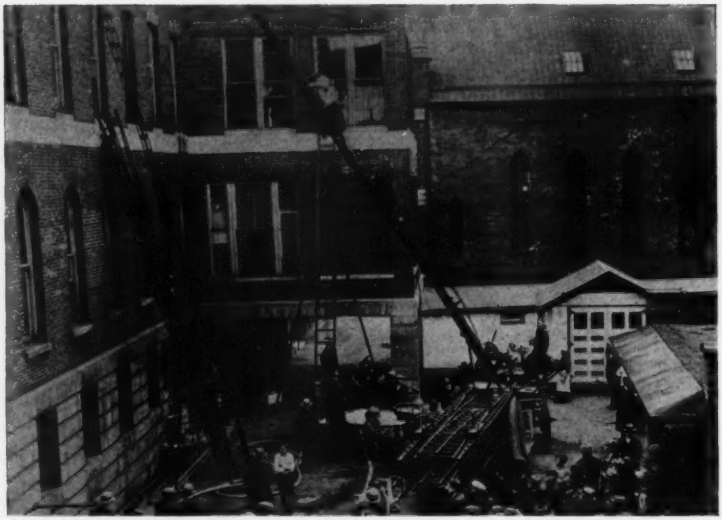
The negatives themselves were in cardboard boxes, in which raw film was received, and were tightly packed on each shelf like books in a bookcase. The doctor's nurse had been filing negatives three-quarters of an hour before the fire and noticed nothing wrong at that time.

The damage to the building was mainly limited to inside trim, fixtures and decorations, and the bulge in the partition. The X-ray apparatus was practically a total loss. The films contained in the closet were practically destroyed. Those stored on the racks in the open operating room were apparently undamaged, the cardboard boxes being only slightly smoked.

This fire clearly shows the hazard of the storage of X-ray films in quantity in buildings of this construction and occupancy without proper vaults, and the necessary steps will be taken to have it removed to outside storage, limiting the supply to that necessary for one day's use. A fire-resistive vault with standard fire door and vent provided with automatic sprinkler head is being built in the X-ray room to house films in future. (H-19929.)

BAKERSFIELD, CAL., SEPTEMBER, 1927. A fire in the main county hospital of Kern County, near Bakersfield, California, was caused by a careless cigarette smoker. An employee, while at work in the X-ray room, laid a cigarette on the edge of a desk or table. Immediately underneath the spot selected as a good place for caching the smouldering fag, was an open drawer filled with X-ray films. It is said that the employee is still a little hazy as to just what happened, but evidently the hot ashes or the cigarette butt itself dropped into the films, causing a flash fire. The heat was so intense and the fire burned so rapidly that damage of approximately $4,000 to the building and contents resulted before the flames could be extinguished. About $1200 of this loss was on the building and $2800 on furniture and X-ray machinery. (H-25054.)

CHELSEA, MASS., FEBRUARY 22, 1928. Fire was discovered in the Chelsea Memorial Hospital in the plate room of the X-ray department in the basement. The fire, brought quickly under control, caused much smoke, some invading the second and third floors. New born babies in the nursery on the second floor were moved by nurses to the nursery cottage a short distance away from the main building. Other nurses quieted the patients. Hospital authorities would make no comment. (H-25646.)



Fire Engineering.

Memorial Hospital, Albany, N. Y. Eight or more lives were lost when X-ray film ignited on March 17, 1928, filling the building with noxious fumes and necessitating the use of ladders and life nets for the removal of patients.

ALBANY, N. Y., MARCH 17, 1928. A fire occurred in a small room on the first floor of the Memorial Hospital used for the storage of films and X-ray equipment. In this room, on wooden shelves around both sides and above the entrance, were stored exposed films packed in ordinary cardboard boxes.

The cause of the fire is undetermined, although a very thorough investigation has been made by several authorities. No one, according to the best information available, had visited the room within a half hour of the time of the discovery of the fire, and the last employee to visit the room declares emphatically that he was not smoking and that everything appeared to be in order when he left.

Efforts were made by the employees to fight the fire, but they were unsuccessful, and fumes from the burning films forced their retreat. In leaving the fire the employees, in their haste and excitement, failed to close the doors between the corridor leading from the film room and the main hallway, in which are the open stairs leading directly to the upper floors. This allowed the smoke and fumes to permeate the building.

By this time the nurses had removed the patients on the affected floors, by the fire escape on the south end of the building and by the elevator, which was kept in operation practically throughout the period of the fire. Several patients refused to be moved and in such cases the doors were kept closed and the windows opened, with the result that the effect from the gas was almost negligible.

Considerable excitement existed. Many patients were taken from the building by firemen by means of extension ladders, and two persons, a maternity patient on the fifth floor and a student nurse on the fourth floor, jumped into life nets below. Neither of them suffered any serious injury. The nurses in the Maternity Ward removed five infants and two mothers to safety by means of the fire escape. They endeavored to go back for the other mothers but were not permitted to do so.

The press reported eight deaths between the night of the 17th and the 19th. It has not been possible to find out definitely how many of these were due to the fumes. At least one was due to exposure and heart attack resulting from shock, and it is said that three or four were directly due to the effect of the smoke and fumes from the burning films.

Due to the fire-resistive character of the building, the fire itself was confined to the room of origin and all the damage was caused by the smoke and gas. Had the door been self-closing, had automatic sprinklers been provided, and had there been a proper vent to the outside of the building as provided by N.F.P.A. regulations, it is probable that the entire loss would have been confined to this room.

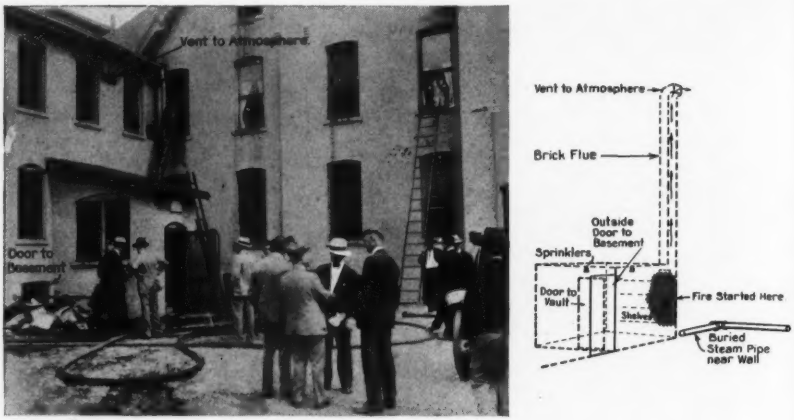
DETROIT, MICH., SEPTEMBER 14, 1928. In the basement of the Delray Industrial Hospital is a brick vault (8 x 7 x 7½ ft.) used for the storage of X-ray film in individual paper envelopes on wooden shelves. An old brick flue extends from the vault to an opening in the outside wall near the second-story windows. The vault is equipped with two automatic sprinklers.

A nurse, who visits the vault two or three times a week, on recent trips had noticed a distinct odor of camphor and had found the air inside so warm that she had to leave the door open a few minutes before entering.

A half hour before noon on September 14, the fire marshal at the near-by Solvay Process Company was seated in the gate house, less than a quarter mile from the hospital. Looking out, he noticed thick, light-brownish fumes escaping from the vault vent. He shouted to others to sound an alarm, and raced to the scene. Men had already started to pull out hose and under his direction quickly had a stream in operation. City firemen coming from their station five hundred feet away soon had another line laid from a street hydrant.

The fumes seemed to envelop the entire building. They also spread up an open basement stairway and penetrated most of the wards, which contained eighty patients in all. A second alarm brought more firemen, to aid in rescue work if the fire should get beyond control. The fumes caused discomfort to some patients, but they were moved to wards on the opposite side of the building, which were carefully ventilated by opening some of the windows, so that no further difficulty was experienced.

Meanwhile the firemen were playing two hose streams against the outside of the vault without apparent effect. Then one of the men, wearing a gas



Factory Mutual Record.

X-Ray Film Fire, Delray Industrial Hospital, Detroit, Michigan. The photograph shows entrance to the basement and the vent from the film vault. The diagram, superimposed on the photograph, shows the location of the vault, and the shading the area of the fire.

mask, smashed the lock on the vault door, and threw the door open, noticing at the same time that the two sprinklers inside were discharging water at good pressure. The two streams were then directed inside the vault and soon extinguished the fire.

An unusual condition was the cause of the fire. The hospital is supplied with steam through an underground pipe from the Solvay Process Company. This pipe passes near the building wall. Opposite the vault it had rusted through, and the escaping steam had dug a channel extending to the corner of the vault where the fire started. Continued heating of the wall soon raised the temperature inside sufficiently to drive off the camphor in the pyroxylin, thus starting slow decomposition. The heat and odor of camphor had led to an investigation and repairs had been made to other sections of the steam pipe, but the serious leak had not been found.

Once started, the decomposition gave off heat, which further increased the decomposition, giving off characteristic brownish-white fumes and finally reached the ignition point of the gases.

After the fire the contents of the vault were immediately taken outdoors. Only about fifteen per cent of the films were found charred. The remainder were somewhat scratched in handling. Films and pyroxylin plastic in general, once heated or charred, are rendered chemically unstable and liable to spontaneous ignition, and their prompt removal in this case was a wise precaution.

Supplies stored in the basement were wet down and windows and doors were broken. The loss was more than $3,200.

Fires Involving Inadequate Fire Protection.

Almshouses.

City Farm, Houston, Texas, August 3, 1919. Coal oil lamps only means of lighting. Fire broke out at 10:34 P.M. in roof space. No fire protection, and fire department could not reach fire due to bad roads.

Ibaco County Infirmary, Tawas City, Mich., April 30, 1920. Sparks from chimney ignited roof. Available fire protection consisted of water pails.

City Almshouse, Moncton, N. B., July 11, 1920. Four 60-gallon chemical tanks were insufficient to cope with fire. No water supply other than two wells used for household purposes was available.

Town Farm, Pepperell, Mass., March 30, 1926. Water supply inadequate.

Washington County Asylum, Salem, Ind., June 21, 1926. Large fire extinguisher on premises, but water supply not available and fire department five miles away.

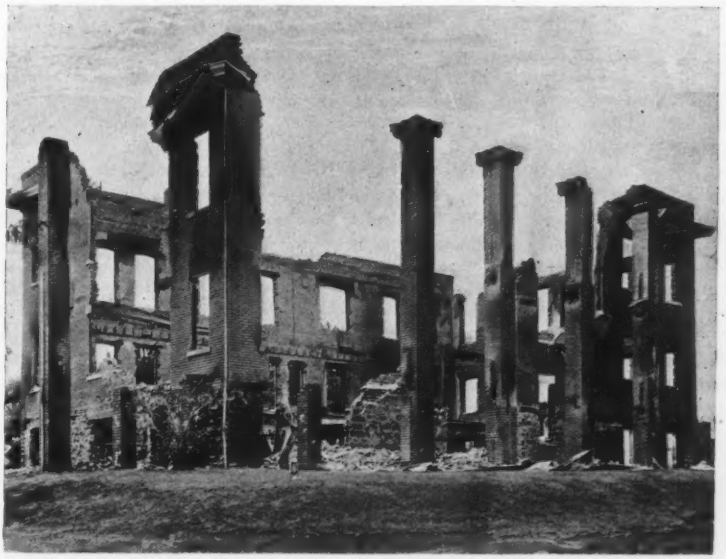
Homes for Aged.

St. Croix County Home, New Richmond, Wis., March 1, 1924. There was a water tank on the premises but the fire pump from the city was unable to connect with it due to different couplings.

Orphanages.

Buckner Orphans' Home, Dallas, Texas, January 2, 1923. Fire apparatus from Dallas responded to this fire, which was six miles beyond city limits. No water available. Total loss, and two boys lost their lives.

Sisters of Holy Cross, Fresno, Cal., March 28, 1925. No water supply. Building located six miles from city line.



Ruins of Crescent Maternity Hospital, Muskogee, Oklahoma, after fire of July 19, 1919. The fire department responded promptly, but the fire had gained too much headway to permit effective use of chemicals; nearest hydrant was 2000 ft. away.

Catholic Mission, Nez Perce Reservation, Lewiston, Idaho, October 4, 1925. Bucket brigade only fire protection. Six boys from five to fourteen years of age perished and building totally destroyed.

Northern Tier Orphanage, Harrison Valley, Pa., January 7, 1927. Frame building on outskirts of small unprotected town with no fire equipment. One child, ill with measles, died from effects of fire and exposure.

Hospitals.

Harney County Hospital, Burns, Oregon, October 29, 1915. No fire protection other than a small gasoline driven pump used for supplying drinking water.

County Infirmary, Iron Mountain, Mich., March 2, 1917. Total loss. No fire protection.

Crescent Maternity Hospital, Muskogee, Okla., July 19, 1919. Located outside of city limits. Nearest hydrant 2,000 feet. Fire was discovered at 10:50 P.M. and fire department called, but fire had too much headway for use of chemicals, and without a pumper water was too far away.

Physicians' and Surgeons' Hospital, Brownwood, Texas, December 18, 1921. Total loss. Water mains were too small to deliver sufficient water for pumper.

Pinckney Sanitarium, Pinckney, Mich., April 11, 1924. Only fire protection consisted of chemicals and five 300-barrel reservoirs.

Rocky Glen Sanitarium, McConnelsville, Ohio, October 23, 1924. Fire protection used consisted of water pails, wet blankets and three one-quart carbon tetrachloride extinguishers.

South Mississippi Charity Hospital, Laurel, Miss., October 11, 1925. Building partially destroyed due to lack of water pressure.

Highland View Hospital, Amherst, N. S., May 25, 1928. Owing to the altitude of the institution, situated at the highest point in the town, water pressure was too low to furnish effective streams.

Insane Asylums.

Wyoming State Hospital for Insane, Evanston, Wyo., September 11, 1917. No fire pump, fire extinguishers or other private protective devices. Water pressure inadequate due to buildings being about the same elevation as city reservoir.

Benton County Infirmary, Oxford, Ind., May 9, 1919. No fire protection. Fire brought under control by bucket brigade.

Manhattan State Hospital, Ward's Island, New York, February 18, 1923. The fire fighting was hampered by the zero weather and the extreme difficulty in getting apparatus to the scene. The New York City force had to go to the fire without equipment, as there was only a small ferry, of insufficient capacity for fire apparatus, to the island. Fireboats had to run hose lines for nearly half a mile before water reached the fire. In spite of these handicaps the fire fighters succeeded in confining the fire to the two upper floors of the west wing. The island's fire department consisted of a fire chief and ten attendants who were detailed for fire service although they also had other duties. The equipment consisted of a motorized fire engine, an ancient horse-drawn engine, a hose cart and a hook and ladder truck.

Washburn-Crosby Mill "A" Fire, Minneapolis.

Report by General Inspection Bureau.

(Member N.F.P.A.)

Fire in Mill "A" of the Washburn-Crosby Company, Minneapolis, on September 16, 1928, resulted in a total loss to the section where the fire originated, and heavy damage to an adjoining section. Fumigation operations were under way in this flour mill at the time of the fire, making it impossible for firemen to enter the building. Automatic sprinklers, which were installed throughout the structure, retarded the spread of fire, but finally failed, presumably because of obstructions to distribution.

Construction and Occupancy.

Mill "A" in which the fire occurred was one of a large group of buildings which together constituted seven individual mill units having a combined capacity of 17,900 barrels of flour per twenty-four hours. Mill "A," which is situated between the fire-resistive Utility Building on the west and fire-resistive Wheat House on the east (see diagram), was erected in 1879, but was in good repair at the time of the fire. The height was seven stories with a cupola, and the ground area 25,900 square feet. The walls were stone, 42 inches thick on the ground floor and 18 inches thick at the top story. A brick interior wall divided the building into two sections. Openings in this wall were protected by tin-clad fire doors; openings into the adjoining buildings on the east and west were similarly protected. Floors were ordinary wooden joisted construction with wooden columns. Ceilings were open joist except in office sections, where they were plastered.

There were a number of floor openings, including two open stairs, an elevator and a number of elevator legs, spouts and chutes, etc.

The north portion of the first floor of the south section of Mill "A" was open for railroad trackage purposes.

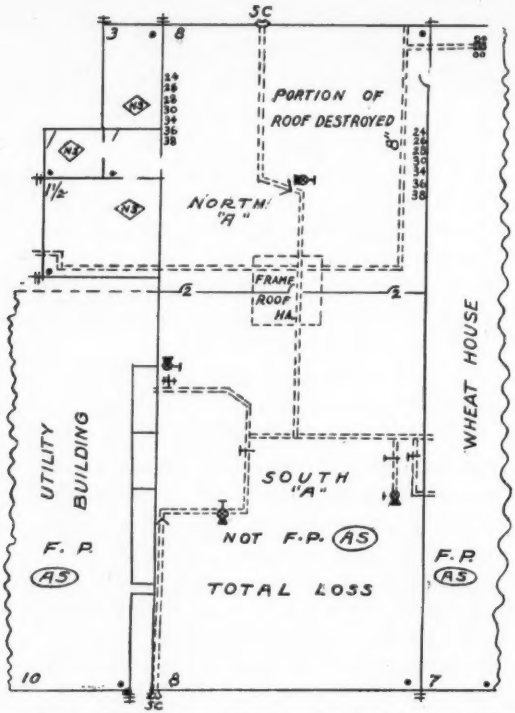
The occupancy of the two sections was as follows:

South Section. 1st floor: shafting, railway tracks. 2nd floor: grinding rolls, buhr stands and pipe shop. 3rd floor: packing, shipping, car tracks, packers, barrel storage. 4th floor: reels, packers and bleacher. 5th floor: grinding rolls, purifying reels. 6th floor: purifying reels, bran dusters, dust collectors, scourers, separators. Roof house: dust collectors, elevator heads, separators, purifying reels, wheat steamer, bran dusters, scourers, metal cyclone, bleacher.

North Section. Storage of flour and feed in bags and unused machinery, except a portion of the 1st floor used for office and engine room, and a small portion of the 2nd and 3rd floors used for office purposes.

Protection.

Mill "A" was provided with sprinkler protection throughout, the piping having been installed by the plant force in 1900, but had been overhauled from time to time so that the equipment was at least equivalent to standard.



Washburn-Crosby Co. Diagram of section involved in fire of Sept. 16, 1928.

The spacing of heads and pipe sizes was better than standard. The south section of Mill "A" was protected by two wet systems and one dry pipe system, the dry pipe system taking care of one small portion of the first floor. The north section was protected by one wet pipe system in the south section. In the south section there were 320 heads per floor or a total of 2,400 heads. In the north section there was a total of approximately 1,050 heads. There was a good water supply, consisting of a primary supply from fire pumps and a secondary supply from city mains and gravity tanks. The available evidence indicated good water supply at ample pressure during the period of the fire.

The usual hand hose and other first aid equipment, watchman's service, etc., was provided, but was not available at the time owing to the closing of the building for fumigation purposes.

The Fumigation.

The mill was undergoing fumigation and this work was being carried on over week ends. Fumigation of the first two units had been started the morning of September 9th and had been carried on without any mishap.

"A" Mill was shut down Saturday morning, September 15th, at 7:30 to prepare for the fumigation process in this unit. At 12:30 P.M. a patrol of eleven watchmen and a master watchman were stationed at designated points surrounding the buildings to be fumigated to prevent anyone from entering. This patrol worked until 3:30 P.M. and was followed by a second patrol of twelve men which worked an eight-hour shift, which was in turn replaced by another patrol of the same number of men at 11:30 P.M. All of these patrols had been instructed to immediately report any unusual happenings. At 1:00 P.M. all employees were ordered to leave the building. The plant fire marshal and his assistants then went through the building to make sure conditions were safe, and he states that apparently everything was in order.

At 3:30 P.M. the final warning to vacate all units to be fumigated was given and fumigating engineers entered and spread calcium cyanide in powder form on all floors of the "A" Wheat House, on all floors of north or warehouse section of Mill "A," the top floors of "C" Mill, and the Wheat House in "C" Mill. Fumigating engineers completed this portion of the work at 5:30 P.M. and after that time it is stated that no one entered any of these buildings.

The superintendent states that electric current and steam were shut off a 6:25 P.M. from all buildings being fumigated except "A" Wheat House.

At 7:00 P.M. liquid hydrocyanic acid was pumped into the south or mill section of "A" Mill, into "B" Mill, the balance of "C" Mill and all of "F" Mill from the outside through pipe lines previously installed in these buildings for this purpose. The entire process of introducing the fumigating materials in all buildings mentioned was completed at approximately 11:30 the night of September 15th.

Story of the Fire.

The first indication of trouble occurred at 12:08 on the morning of September 16th, when a water flow alarm was received at the local central station from system No. 14 located in the east side of the south section of "A" Mill. At this time the automatic steam pump started and showed a pressure of 100 pounds. It is said a pressure of between 90 and 100 pounds was maintained thereafter. The plant fire marshal immediately started an investigation, which could only be made from the outside of the building due to fumigation, the gases at this time being of a very deadly nature. He and his assistants were unable to locate any signs of smoke or fire, but the plant fire marshal called fire department headquarters and requested they send apparatus equipped with searchlights. The department answered promptly, and began an outside tour of the building, flashing their searchlights on the windows and building to see if they could detect fire or smoke. Although no absolute evidences of fire or smoke could be discovered, the fire department captain and plant fire marshal could see water coming through the ceiling of the train shed and dropping on the railroad tracks below. A few minutes later the captain believed he smelled smoke, and as an additional precaution called

Ruins of Mill "A," looking from roof of Utility Building.

fire department headquarters and requested additional apparatus be sent to be in readiness on the ground. Upon returning from the telephone he noticed a small flame at the bottom of a hopper inside the train shed at about the center of the building where water was first seen running.

A line from a near-by hydrant was brought into play on this flame from the outer edge of the train shed. Entrance to the shed was not possible because of the danger of concentration of fumigating gas in the train shed. This stream proved ineffective, due to the fact that firemen could not get into the train shed to direct stream up in the hopper. At this time additional apparatus arrived. The sprinkler equipment was in operation and, with the possibility of extinguishing the fire or of the fire burning itself out, officers hesitated to vent the building, thereby endangering lives with the gas and creating a draft which would aid in the spread of the fire.

At 1:21 A.M. a water flow alarm was received at the local central station from system No. 13 in the west side of the south section of "A" Mill. At 1:30 A.M. a water flow alarm was received in the local central station from system No. 12 in the north section of "A" Mill.

After the second valve tripped, one of the electric pumps was put in service, and after the third valve tripped a second electric pump was to have been started, but when the plant fire marshal arrived at the pump house it was found the current was off, due to circuit breakers having tripped out. There apparently was no other reason for the current being off, as the following day the circuit breakers were reset and the pumps operated without any trouble. It is to be noted here that while the pumps were accessible, the circuit breakers in the line furnishing current for the pumps were located in the switchboard vault of the Humboldt Mill, and while no fumigating was being done in this room, gases had worked in and it was impossible for anyone to enter and reset the circuit breaker that night. The failure of the current did not materially affect the water supplies, due to the fact that several hose lines from the fire department pumpers were connected to the fire department connections supplying the sprinkler equipment.

The flames and smoke were now plainly noticeable in the northeast corner of the south section of the building, and at 1:39 the battalion chief called for more apparatus. The assistant chief responded to this call and at 2:17 A.M. sent in a 3-11 alarm, which brought eight engine companies, four truck companies and two battalion chiefs. Special calls for apparatus brought ten additional engine companies and two truck companies.

Due to the fact that the burning building as well as adjoining buildings were heavily charged with hydrocyanic acid gas, it was impossible for firemen to stay in close proximity to any of the buildings, and as a consequence the only way of playing streams into the burning building was through windows which could be broken by streams, until such time as the roof fell in. By this

Looking south from roof of north section of Mill "A."

time the fire had gained such headway that little or no good was accomplished in the south section of the building except to cool the fire and prevent it from spreading to adjoining buildings. The floors in the south section were rapidly weakened by the fire, and, unable to withstand the weight of the machinery resting on them, fell to the bottom. The fire in the north or warehouse section was confined to the cupola and roof.

Fire was practically under control by 5:30 A.M. September 16th, but rekindled at different times during the day, in spite of the fact that the equipment and firemen were still on hand.

It was not until about 3:00 P.M., September 16th, that the fumigating engineers could enter the adjoining buildings and vent them in such a manner that the firemen were able to bring their lines through these buildings and play on the fire from these advantageous points.

At 10:31 the same night a water flow alarm was received in the local central station from system No. 15 in the "A" Wheat House, which adjoins "A" Mill on the east. Upon investigation it was found heat had communicated through a belt opening in the wall and fused two heads, one on the fourth floor and one on the sixth floor.

The ruins were still smouldering on September 18th and firemen were being maintained on duty, although the fire was practically extinguished.

The origin or cause of the fire has not been determined.

Damage.

Practically the entire south section and all its contents were destroyed. The roof and the cupola of the north section of the building were badly burned and will have to be replaced. The contents of this section were heavily damaged by water. A water loss can also be expected in the Wheat House of "A"

Mill and the Utility Building, but no fire damage whatsoever resulted in either of these buildings.

Conclusions.

It is evident that fumigation operations should not be conducted on such a large scale. Gas masks of a type which will permit persons to enter a building under a maximum concentration of gas in the event of any trouble should be provided. If such type of mask had been available firemen could have entered the building following first alarm and this fire would have been easily extinguished.

It is evident this was a slow smouldering fire at the start, being held in check by the sprinkler equipment, which is borne out by the fact that one hour and thirteen minutes elapsed between the tripping of the two systems which were in the same floor area. While the sprinkler equipment did not extinguish the fire in the south section of the mill, it is evident that it prevented the spread of the fire to adjoining buildings and to the major portions of the north section. It is assumed that the distribution of water was obstructed by spouts, bins, etc., and that the fire either originated in or spread to these locations where water from the sprinklers could not reach, gradually working up through the building, gaining headway until the floors gave way and destroyed any further effectiveness of the sprinkler system.

Considering the handicap under which it operated, the fire department did all that could be expected.

A Good Servant But A Bad Master.

Riverside Church, New York.
MAY IT SOON RISE AGAIN
BEWARE LIGHTED CANDLES WINDOW CURTAINS
DON'T OVERHEAT YOUR FURNACE.
BE CAREFUL THIS DOESN'T HAPPEN

Providence Journal.

McDonough School Fire, Baltimore County, Md.

By William C. Todd (Member N.F.P.A.),
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One hundred and seventy-five students were roused from their sleep by a fifteen-year-old bugler and made their way to safety, when fire destroyed the main building of the McDonough School, near Pikesville, Baltimore County, Md., on October 24, 1928, resulting in a fire loss of approximately $251,589. Four persons, including two firemen, were injured. One student was burned on the arms and an instructor fell and sprained his ankle.

The fire was the second at the institution in one week. It was the third since Christmas of 1926, when a blaze in the linen room was extinguished by four students. The fire immediately previous was discovered Monday, October 22, 1928, but authorities were unable to determine if there was any connection between the two fires.

Two negro employees discovered the fire in the linen room at 3:20 A.M. They immediately notified the principal of the school and fought the blaze with a small garden hose and fire extinguishers. The fire became so intense that the men had to leave the cellar, and took their stand on a stairway with a garden hose in an attempt to prevent the blaze from spreading up the steps. They were driven off by the heat. The Pikesville fire department was immediately notified, and as soon as they arrived they sent in a call for more engines and for volunteers from the surrounding county.

The firemen were handicapped by lack of water. The school had two fire hydrants on the grounds supplied by a 13,000-gallon tank located inside the building. Students and instructors had been using streams supplied from this source since the discovery of the blaze and there was not sufficient supply to serve the engines for any length of time.

When additional county fire apparatus arrived the hose of six companies was used to bring water from Gwynn Falls Run. Five engines were used in relays to boost the pressure for this one stream. Realizing that this supply was not sufficient, the chief of the Baltimore County fire department sent in a call for additional engine companies.

Practically all of the available fire apparatus in Baltimore County was mustered to fight the blaze. Calls were sent to Baltimore for aid, a distance of about six miles, and the chief engineer of the Baltimore city department sent five engine companies, a truck company, and a chemical wagon to assist the county department.

After considerable delay the firemen managed to get another line of hose laid from Gwynn Falls Run and, with two streams, efforts were made to pre-

Fire in McDonough School, showing extent of fire after spread of flames throughout building by means of vertical openings.

vent the flames from reaching the main or front part of the building, which was constructed in the form of the letter T.

By this time the fire, which started in the linen room, had spread through the basement, and the firemen, working in intense heat, were apparently getting it under control by stuffing all vertical openings with blankets to shut off the draught. However, when the additional fire companies arrived smoke was so intense in the basement that the blankets in the openings were removed. This proved disastrous, for immediately the flames made their way up an elevator and clothing chute that runs through the building and ignited the roof.

The blaze was so hot that the glass in the windows was melted. The school bell tower and several other towers on the roof of the structure collapsed, and the firemen had to retreat to escape being caught under bricks and blazing timbers. Telephone communication of the school was destroyed, but the telephone company sent an emergency squad which installed three lines, over which the school authorities called the parents of the students to assure them that their sons were safe.

The gymnasium, about seventy feet in the rear of the main building, was saved by a shifting of the wind. But this shift of wind for a time threatened the infirmary, a large frame building. This was saved by a volunteer fire company, which put out blazing embers carried from the main building. There

Fire in McDonough School near Pikesville, Maryland. The hose of six companies was used to bring water for one stream from a small river, and five engines were used in relays to boost the pressure.

were no patients in the infirmary at the time. The boiler room in the rear of the main building was saved by the combined efforts of the city and county firemen.

The most noticeable fact brought out by this fire is the lack of adequate fire protection facilities and water supply, so true of rural private schools and small colleges located at some distance from a protected village or town. A fire alarm box in the building, equipped with auxiliary stations which could have been sounded immediately on discovery of the fire, would have facilitated the response of the county fire department and might have prevented the spread of the fire beyond its point of origin.

Fires in Which There Was a Loss of Life.

These notes are intended to point out typical conditions under which loss of life has occurred that they may be known and guarded against.

Automobile Accident.

H-26396. RED WING, MINN., AUGUST 20, 1928. Four men were burned to death and six other persons were injured when a large motor coach, carrying eleven passengers between Chicago and the Twin Cities, skidded at a curve of the slippery highway and crashed into a truck. The bus careened to the side of the road, where it partially tipped over on its side and burst into flames. Four men could not be released from their seats and they were burned to death. Others escaped through broken windows by their own efforts or were rescued by fellow passengers.

Ashes from Stove Ignited Clothing.

L-342. CHICOPEE, MASS., DECEMBER 24, 1928. An elderly woman died in a hospital from burns she received when her clothing ignited while she was removing ashes from a kitchen stove. Her screams attracted two girls residing with her. They attempted to tear off the burning clothing, but became frightened and ran from the house. A neighbor tried vainly to extinguish the flames. Nothing could be done to save the woman's life.

Children Left Alone in House.

L-335. FREEHOLD, N. J., DECEMBER 8, 1928. Fearing that her two children might tamper with the radio while she was making a morning call, the mother locked them in the kitchen and opened the draft of the stove in order that they might be kept warm. The mailman discovered the house on fire and gave the alarm. When the firemen reached the children both were dead. The oldest boy, four years old, had tried to escape, but the two year old child was dead in his chair. The range is believed to have overheated and caused the fire.

Children and Matches.

L-352. HOLYOKE, MASS., NOVEMBER 25, 1928. Hearing shouts from her three-year-old son, the mother, who had left her children alone upstairs, rushed up from the cellar and snatched her two-month-old daughter from a burning baby carriage which had been set on fire by the boy, who was playing with matches. The infant died from its burns.

Night Club Fire.

H-26958. NEW YORK, N. Y., DECEMBER 16, 1928. Four men lost their lives and several others were seriously burned and half a dozen more escaped with slight injuries when a fire swept the second floor of a social club in the Bronx shortly before daybreak. The proprietor of the club made three trips back into the burning clubrooms to assist patrons to the fire escape, but was trapped when he made a fourth trip for his money. Another man was suffocated and then burned to death when he went in to rescue the proprietor. It is

said that a lighted cigarette set fire to Christmas decorations in the rear room. A mad panic followed the discovery of the fire. Two other men died of burns, making a total of four.

Fire Fighting.

H-26866. CAMDEN, N. J., NOVEMBER 8, 1928. One fireman was killed and twenty-five others were injured or overcome when escaping gas from a leaky main exploded and set fire to an automobile body plant. The man killed was a fireman attached to the plant. His body was discovered in a coal pit by a fireman who was lowered by a rope into the flame filled cellar in an effort to rescue him. The firemen were fighting a fire on the second floor when the explosion occurred.

L-333. BROCKTON, MASS., DECEMBER 9, 1928. Two wires which had crossed and started a small fire on the outside of his house caused the death of a man when he tried to pull the wires apart in an effort to extinguish the blaze. He was electrocuted.

Fire from Fireplace.

L-355. DANVILLE, VA., DECEMBER 10, 1928. A man sixty-five years old was burned alive at his home when flames from the fireplace apparently ignited his clothing. Suffering from a chill, he garbed himself heavily and drew close to the fire, sending his child on an errand. When the child returned the father was lying on the floor dead with his clothing burned off.

Gasoline and Kerosene.

L-349. FREDERICK, MD., DECEMBER 17, 1928. A woman was fatally burned and her husband suffered severe burns when kerosene was poured on a low wood fire to stimulate it. The stove apparently exploded and the woman's dress, sprayed with oil, became a mass of flames.

L-339. ANCHOR, N. MEX., NOVEMBER 21, 1928. A fourteen-year-old girl received fatal burns when by mistake she used gasoline for kerosene in kindling a fire. She died ten days following the accident.

Hotel Fires.

H-26988. AKRON, OHIO, DECEMBER 25, 1928. Six guests lost their lives and seven others were injured when fire swept the basement of a hotel on Christmas morning. The victims, along with eighty other persons who were in the building when the flames broke through the basement, were trapped in rooms and corridors of the hotel. Smoke rose up a clothes chute from the basement and filled the structure. All but one of the victims had rooms on the third and top floors of the four-story brick building. The guests on the lower floors escaped through the smoke. The fire started by spontaneous ignition.

H-26971. HAZARD, KY., DECEMBER 15, 1928. Five lives were lost when fire destroyed a five-story brick hotel. The fire started on the ground floor and swept up a wooden stairway and quickly enveloped the building. The persons who lost their lives were trapped on the top floor.